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CONTRACT 169

REPORT NO. 3

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Barbados, 16-23 November 1965)

SPACE INSTRUMENTS RESEARCH, INC.

ERL CONTRACT 169 REPORT 3

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Barbados, 16-23 November 1965)

Prepared for

U. S. Army
Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

Contract No. DA-01-009-AMC-169(X)

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INTRODUCTION

A continuing study of upper atmospheric winds over the lower West Indies has been made possible by the firing of high altitude ballistic probes from a sixteen-inch gun located on the Island of Barbados. These firings are being carried out by the U. S. Army Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, under the direction of Dr. Charles H. Murphy, and by the Space Research Institute of McGill University, Canada, under the direction of Dr. G. V. Bull.

Atmospheric winds are studied by releasing chemical trails from the gun-fired probes during the upper portion of their trajectories. To date, the primary chemical which has been released is trimethyl aluminum (TMA). TMA produces a chemiluminescent glow in regions of the atmosphere above 85 kilometers, thus allowing the trails to be photographed while being distorted by upper atmosphere winds. The photographs are then reduced to provide wind information by SIR, using computer techniques.

The purpose of this report is to summarize results of these studies for the period from November 16 through November 23, 1965. Previous results are covered in Technical Report No. 1, issued November, 1965, and Technical Report No. 2 issued March, 1966.

DATA ACQUISITION

The chemical trails are formed almost vertically over the island of Barbados (longitude 59.4°W, latitude 13.0°N) and extend from an altitude of 85 kilometers through apogee. In some firings, TMA is also released on the down leg of the trajectory. To the unaided eye, the chemical release first appears as a straight white trail resembling a jet contrail. Within a minute or so, the trail is distorted into strange shapes by the upper atmospheric winds (see Fig. 1) and fades from view within approximately fifteen minutes after initial release.

Space Instruments Research has established eight photographic triangulation stations on the islands of Barbados, St. Vincent, Grenada, and Tobago, with two sites per island. These islands are located to the west and south of Barbados at distances of 190 to 290 kilometers (see Fig. 2). While only one site on each of two islands is required for data reduction purposes, the eight sites have been found necessary because of cloud conditions in the area.

Equipment at each site, built by SIR, consists of a camera unit containing two seven-inch focal length cameras mounted on a concrete pedestal, and an electronic control. Cameras are automatically pulsed to take exposures of 3, 6, and 12 seconds duration every 30 seconds.

Since commercial power is either unreliable or unavailable at most site locations, SIR has developed a battery operated 115-volt power supply for the control equipment. The power supply is tuning-fork controlled and provides 60 cycle power with an accuracy of 0.005% for the

camera programmer so that pictures can be taken simultaneously at each site. A data chamber mounted on each camera unit records time, shot number, and site information in the corner of each frame of film.

A short wave radio net connecting all sites and the launch control center has been installed by SIR to enable the launch control officer on Barbados to be informed of weather conditions on the islands and to synchronize picture-taking operations with the firing of the gun. Most sites are operated by local personnel who have been trained by SIR.

During a typical night's operation, the gun is fired at one to two-hour intervals, from sunset to sunrise. Photographs are taken by all sites during the time that the trail is visible. The film is returned to Atlanta for processing and data reduction.

DATA REDUCTION

Several computer programs have been developed which make it possible to calculate upper atmosphere winds from measurements made directly on the photographs of the luminous trails.

Since the method used is basically three-dimensional triangulation using spherical trigonometry, it is necessary to know precisely the direction each camera was pointed during a given firing. The direction is determined by first taking accurate measurements of the locations of several star images on the film, and then computing the azimuth and elevation of the optical axis of the camera by means of a computer program. This computer program makes use of the celestial coordinates of some 6,000 stars which have been stored on magnetic tape.

Wind speeds and directions are then determined from the location of the trail in space at a succession of known times. The location is found, using either a point location program or a trail location program, or both, and depends on the nature of the chemical release.

Point location method. If the chemical release exhibits discrete points (resulting either from turbulence or from the nature of the release mechanism) and these points can be identified on films from two or more islands, the point location program can be used to calculate the position of each point in longitude, latitude, and altitude above sea level.

These calculations are made from data taken at successive times. A wind program is then used to calculate both vertical and horizontal winds from the motion of these points as a function of time.

Trail location method. Most of the chemical releases produce a smooth trail having few, if any, identifiable points. In such cases, film coordinates of a large number of incremental points along the film image of the trail are fed into the computer from data from two or more islands. The trail location program attempts to triangulate each point from one site with many points from another site, finally choosing points from both sites whose optical paths from camera into space form the closest spatial intersection. After doing many hundreds of such calculations, the computer is able to construct coordinates for a mathematical curve in the shape of the trail in space. Then, as with the point location program, winds can be determined from the motion of the curve with time. Here, however, it must be assumed that vertical winds are essentially zero. This assumption is borne out by previous studies which have shown vertical winds in this altitude region to be of the order of a few meters per second compared to horizontal winds ranging up to 150 meters per second.

Corrections for variables such as atmospheric refraction, rotation of camera about optical axis, and camera focal length, are incorporated into the programs to maintain high accuracy. Focal length and camera rotation are in fact calculated from measurements of the positions of star images on the films.

INTERPRETATION OF DATA

In the remainder of this report, horizontal wind velocities are presented in tabular form and in plots of wind speed, direction, and components.

Winds were calculated at altitude intervals of one kilometer. Points on the various plots show the actual computed result, as listed in the table preceding the plot. A curve has been fitted to each set of points to aid in detecting wind patterns and to indicate reliability of the plotted results. Each curve has been drawn with a knowledge of intermediate results leading to the wind calculations and of the consistency of the winds as calculated between each of the five or six time intervals used. In cases where point-to-point curve fitting was not thought to reflect actual variations in wind speed, direction, or components, a more appropriate smooth curve has been drawn. Otherwise, the curves are fitted directly to the data points. Results of certain portions of the trails are at times less accurate than others due to the spacial orientation of those trail segments relative to the available photographic stations. Less accurate data also can result from photographs obscured by haze and clouds and from trails of short duration.

Wind speed plot. This plot shows the speed of the wind vector in meters per second as a function of height in kilometers above sea level.

Wind direction plot. The wind vector is considered to point in the direction toward which the wind is moving. The direction plot shows the direction of this vector in degrees clockwise from north as seen from above. Thus, a wind direction toward the east would be 90 degrees.

Wind components plot. While plots of wind direction and speed do completely describe the wind vector, it has been found helpful in studying wind patterns to present the north-south and east-west velocity components of the vector. In the north-south plot, north is positive; south is negative. In the east-west plot, east is positive, west negative. Components are plotted in meters per second versus height in kilometers.

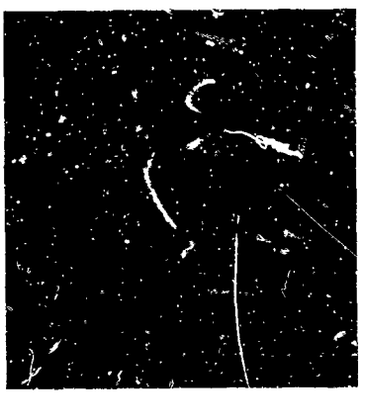
The wind direction and components described above are referenced to true north. In addition, components have been calculated relative to magnetic north for comparison with other ionospheric phenomena. These components are not plotted, but are listed in the tabulations preceding each set of plots.

Fig. 1

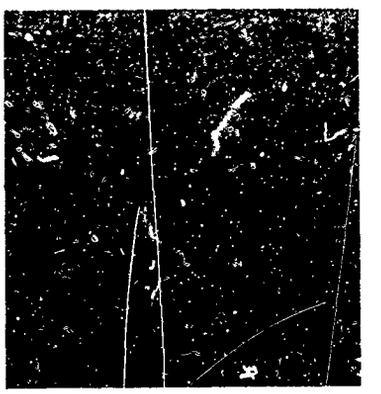
Photographs of firing Christ Church

Photographs taken 154 seconds after firing:

Barbados



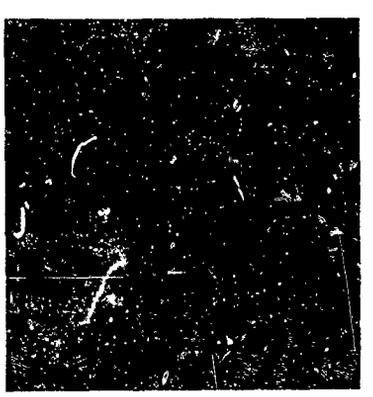
St. Vincent



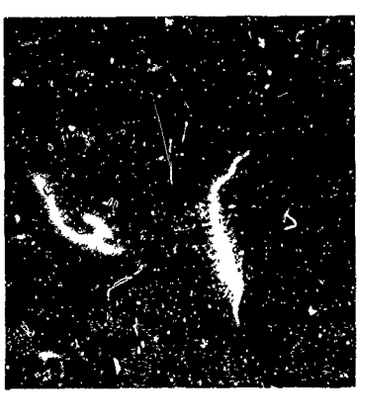
Tobago

These pictures were taken from three islands just as the vehicle reached apogee. Note that the winds have already distorted the trail. ~~Numbers indicate altitude in Kilometers.~~

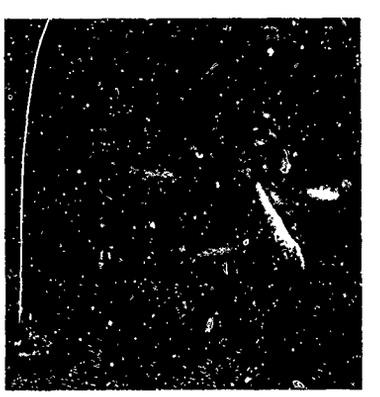
Photographs taken 244 seconds after firing:



Barbados



St. Vincent

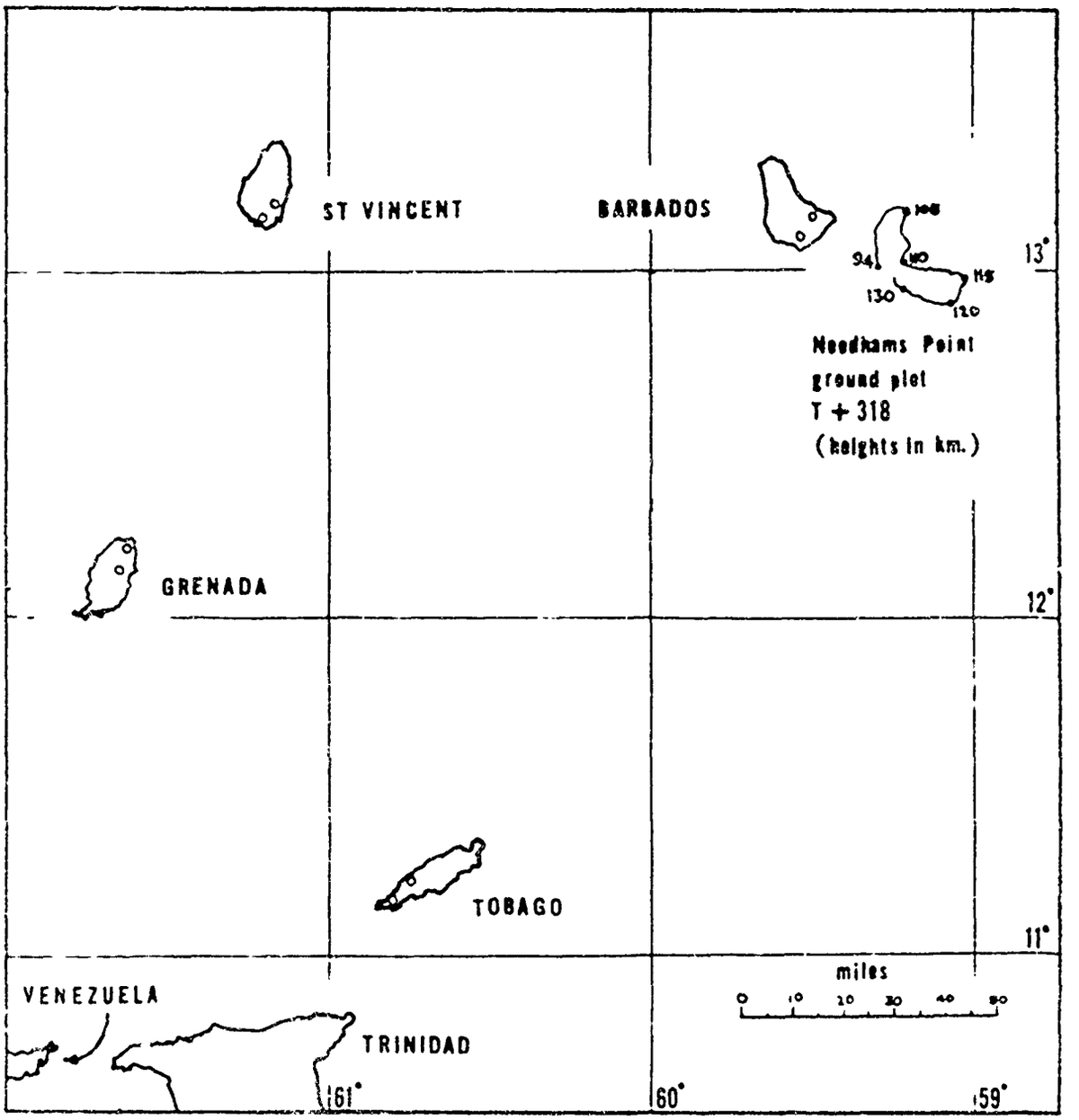


Tobago

This set of pictures was taken at completion of the downtrail. The uptrail shows the continued effect of the winds, while the lower part of the downtrail is new and only slightly distorted. Stars can be seen in the background of these pictures. The positions of these stars are used to determine the exact direction each camera was aimed.

Fig. 2

Location of S.I.R. photographic stations



Two stations are located on each of the four islands, as shown. While only one station on each of any two islands is sufficient for determination of winds by triangulation, several stations were found necessary because of prevalent cloud conditions in the area. Accuracy of the data reduction is also increased by use of films from more than two islands.

SYNOPSIS OF RESULTS

The following comments may be helpful in interpreting the data contained in this report. Only those shots with unusual characteristics are discussed.

No. 30, Yorkshire

This release differed from the others in that cesium, rather than TMA, was released. The chemical was released as a point, rather than a trail, at T + 94 seconds at an altitude of 101 km, remaining visible for roughly 100 seconds.

The release showed a considerable vertical motion, about 38 meters per second, rising to above 105 km before fading from view. The wind is shown plotted for 103 km, the average height.

No. 31, Christ Church

Uptrail and downtrail results were quite similar for this trail. While there were some differences between uptrail and downtrail velocities, at all altitudes the possible errors were large enough that there may be no actual differences between up and down winds.

No. 32, Dover

Uptrail results were generally better than downtrail, so the curve was fitted closer to uptrail results over most of the trail. However, above 115 km there seemed to be a significant difference between up and down results, so two curves were drawn.

No. 33, Foul Bay

Here up and down results were in fair agreement over all of the trail except for 103 through 105 km. Intermediate steps in the data reduction showed that while the maximum south wind occurred at 105 km

in the uptrail, the maximum was around 103 km in the downtrail.

No. 41, Rockley

Note that in the "wind direction" plot, altitudes 129 and 130 km do not fit the curve at all well. This is because the wind was practically "calm," thus wind direction has little meaning and large possible errors when calculated.

No. 42, Seawell

Seawell had poor film data, causing part of the wind profile results to be quite poor. The lowest part (from 93 to 103 km) was good enough that we could put a curve through the data points with some confidence. However, from 104 to 110 km, we feel that there may be considerable error in the plotted points, thus a dotted curve was drawn. Above 104 km the results were better. Note that at 110 km a calm wind caused poor direction results, as with shot Rockley.

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TABLE OF TRAIL INFORMATION

Trail No.	Name	Date	Time (AST)	Altitudes (km)
30	Yorkshire	16 Nov. 1965	18:15:00	101
31	Christ Church	17 Nov. 1965	18:15:00	92-119
32	Dover	17 Nov. 1965	19:34:00	91-122
33	Foul Bay	17 Nov. 1965	23:15:00	93-127
34	Gun Hill	18 Nov. 1965	00:45:00	96-127
35	Indian Ground	18 Nov. 1965	03:30:00	98-117
36	Jamestown	18 Nov. 1965	05:08:00	93-119
37	Maxwell	22 Nov. 1965	18:09:00	94-120
38	Needhams Point	22 Nov. 1965	19:30:00	93-134
39	Paragon	22 Nov. 1965	22:59:00	99-126
40	Queens Fort	23 Nov. 1965	01:31:00	100-133
41	Rockley	23 Nov. 1965	03:28:00	95-138
42	Seawell	23 Nov. 1965	05:16:30	91-130

TABULATIONS AND PLOTS

Thirteen Trail Releases - November 16-23, 1965

TRAIL NO. 30 YORKSHIRE

BARBADOS 16 NOVEMBER 1965 18:15:00

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
103.0	337.7	92.4	85.5	-35.1	90.8	-17.1

NO PLOTS ARE SHOWN FOR THIS RELEASE

TRAIL NO. 31 CHRIST CHURCH

BARBADOS 17 NOVEMBER 1965 18-15-00 AST

UP TRAIL

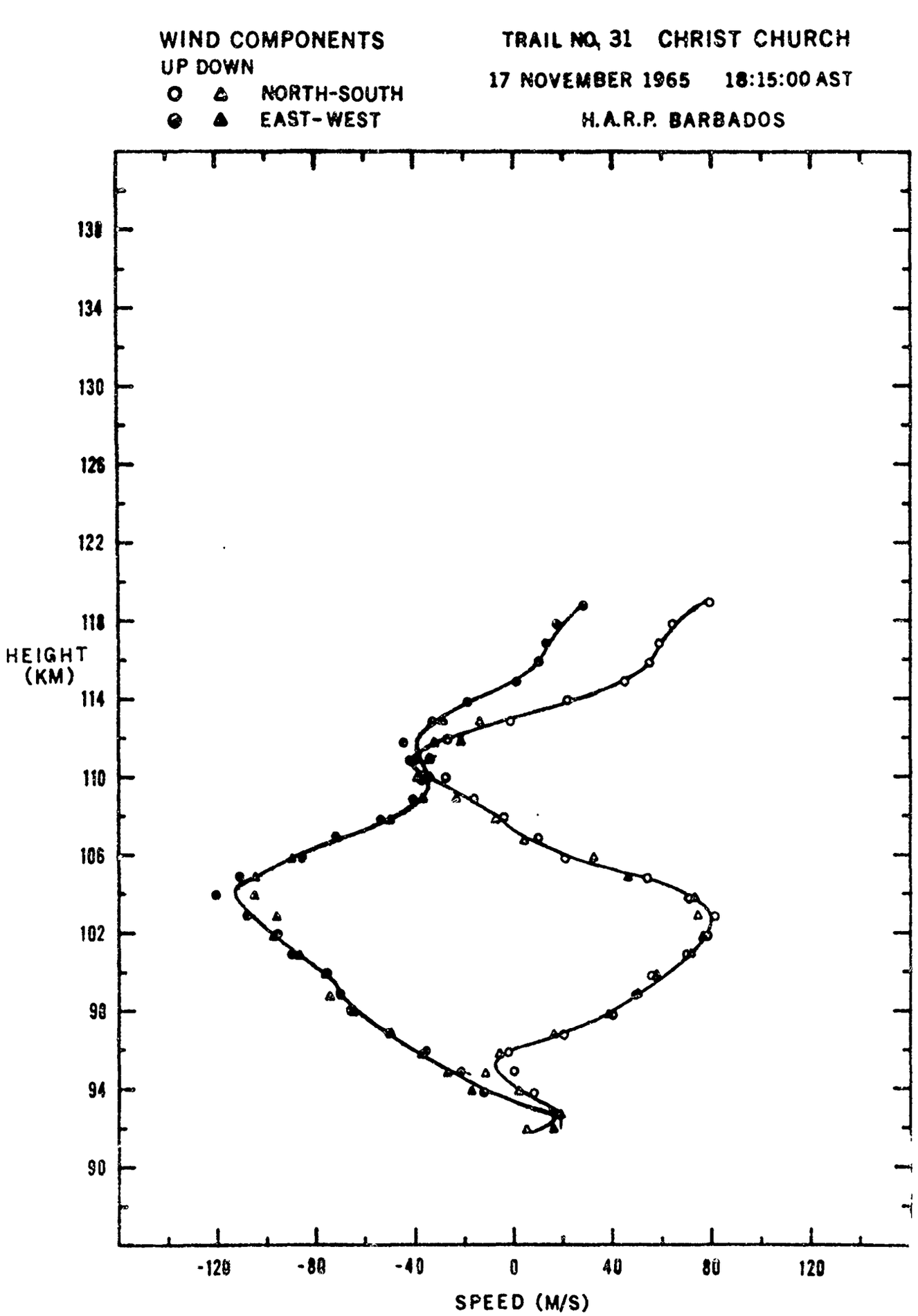
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
93.0	45.7	27.4	19.1	19.6	14.7	23.1
94.0	303.6	14.9	8.3	-12.5	10.7	-10.6
95.0	271.4	22.1	0.6	-22.1	5.1	-21.5
96.0	268.1	36.7	-1.2	-36.7	6.2	-36.2
97.0	291.2	55.7	20.2	-51.9	30.3	-46.7
98.0	301.2	77.6	40.2	-66.4	52.8	-56.9
99.0	304.6	85.8	48.7	-70.6	62.0	-59.3
100.0	307.0	94.3	56.8	-75.3	70.9	-62.3
101.0	307.6	114.8	70.1	-90.9	87.0	-74.8
102.0	308.8	124.9	78.3	-97.3	96.4	-79.5
103.0	307.3	136.3	82.6	-108.3	102.8	-89.4
104.0	300.4	141.4	71.6	-121.9	94.8	-104.9
105.0	296.1	124.4	54.8	-111.7	76.3	-98.3
106.0	284.1	88.4	21.6	-85.7	38.5	-79.6
107.0	278.5	71.7	10.6	-70.9	24.7	-67.3
108.0	266.5	52.9	-3.2	-52.8	7.5	-52.4
109.0	247.9	44.1	-16.6	-40.9	-8.0	-43.4
110.0	230.2	46.5	-29.7	-35.7	-21.9	-41.0
111.0	223.8	58.5	-42.2	-40.4	-33.2	-48.1
112.0	238.4	50.6	-26.5	-43.1	-17.2	-47.6
113.0	268.8	32.1	-0.7	-32.1	5.8	-31.6
114.0	321.9	28.8	22.6	-17.7	25.7	-12.8
115.0	3.1	45.8	45.7	2.5	44.3	11.7
116.0	10.7	56.5	55.5	10.5	52.2	21.5
117.0	13.4	61.0	59.4	14.1	55.3	25.8
118.0	15.5	67.7	65.2	18.1	60.2	30.9
119.0	19.4	85.0	80.2	28.2	72.8	43.8

TRAIL NO. 31 CHRIST CHURCH

BARBADOS 17 NOVEMBER 1965 18-15-00 AST

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
92.0	69.1	18.0	6.4	16.8	2.9	17.7
93.0	44.3	26.9	19.3	18.8	15.1	22.3
94.0	279.1	15.4	2.4	-15.2	5.4	-14.4
95.0	247.2	28.1	-10.9	-25.9	-5.4	-27.6
96.0	261.4	36.8	-5.5	-36.4	2.0	-36.8
97.0	289.8	50.4	17.1	-47.4	26.3	-43.0
98.0	301.7	74.3	39.0	-63.3	51.0	-54.1
99.0	304.7	88.4	50.4	-72.7	64.1	-61.0
100.0	307.9	95.6	58.7	-75.5	72.8	-62.1
101.0	310.3	112.8	72.9	-86.0	88.8	-69.5
102.0	308.5	125.0	77.8	-97.8	96.0	-80.0
103.0	308.2	123.5	76.3	-97.1	94.4	-79.7
104.0	305.4	128.2	74.3	-104.5	93.9	-87.3
105.0	294.3	114.1	46.9	-104.0	67.0	-92.4
106.0	290.8	93.4	33.2	-87.3	50.2	-78.8
107.0	273.9	70.1	4.7	-70.0	18.8	-67.6
108.0	262.6	48.8	-6.3	-48.4	3.6	-48.7
109.0	238.7	41.8	-21.7	-35.7	-14.0	-39.4
110.0	221.8	51.2	-38.1	-34.2	-30.4	-41.2
111.0	219.3	54.0	-41.8	-34.2	-34.0	-41.9
112.0	236.7	37.3	-20.5	-31.2	-13.8	-34.7
113.0	248.0	31.9	-12.0	-29.6	-5.8	-31.4


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 31 CHRIST CHURCH
17 NOVEMBER 1965 18:15:00 AST
H.A.R.P. BARBADOS
138
134
130
126
122
118
114
110
106
102
98
94
90
HEIGHT (KM)
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

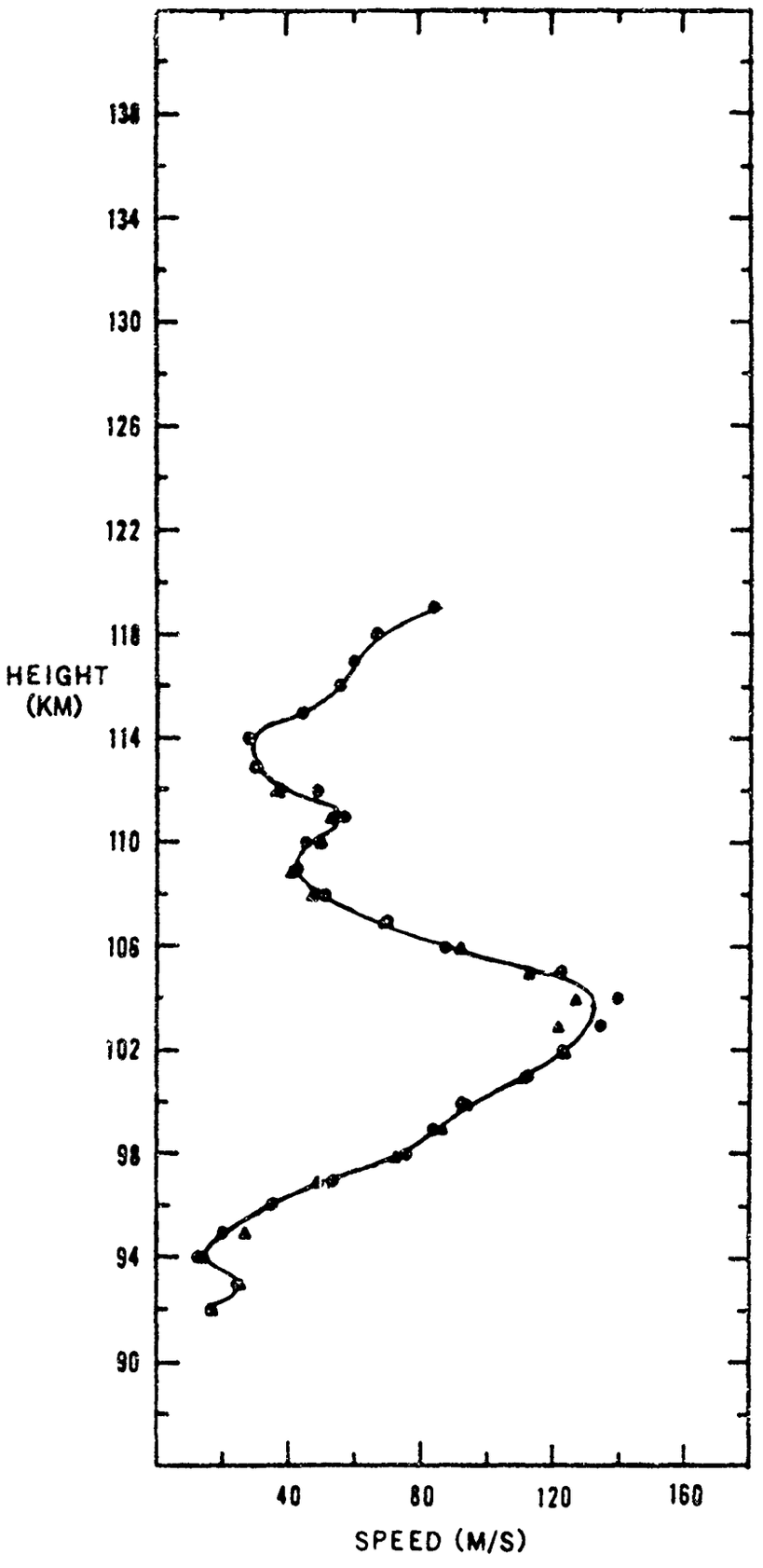
TRAIL NO. 31 CHRIST CHURCH

17 NOVEMBER 1965 18:15:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



WIND DIRECTION

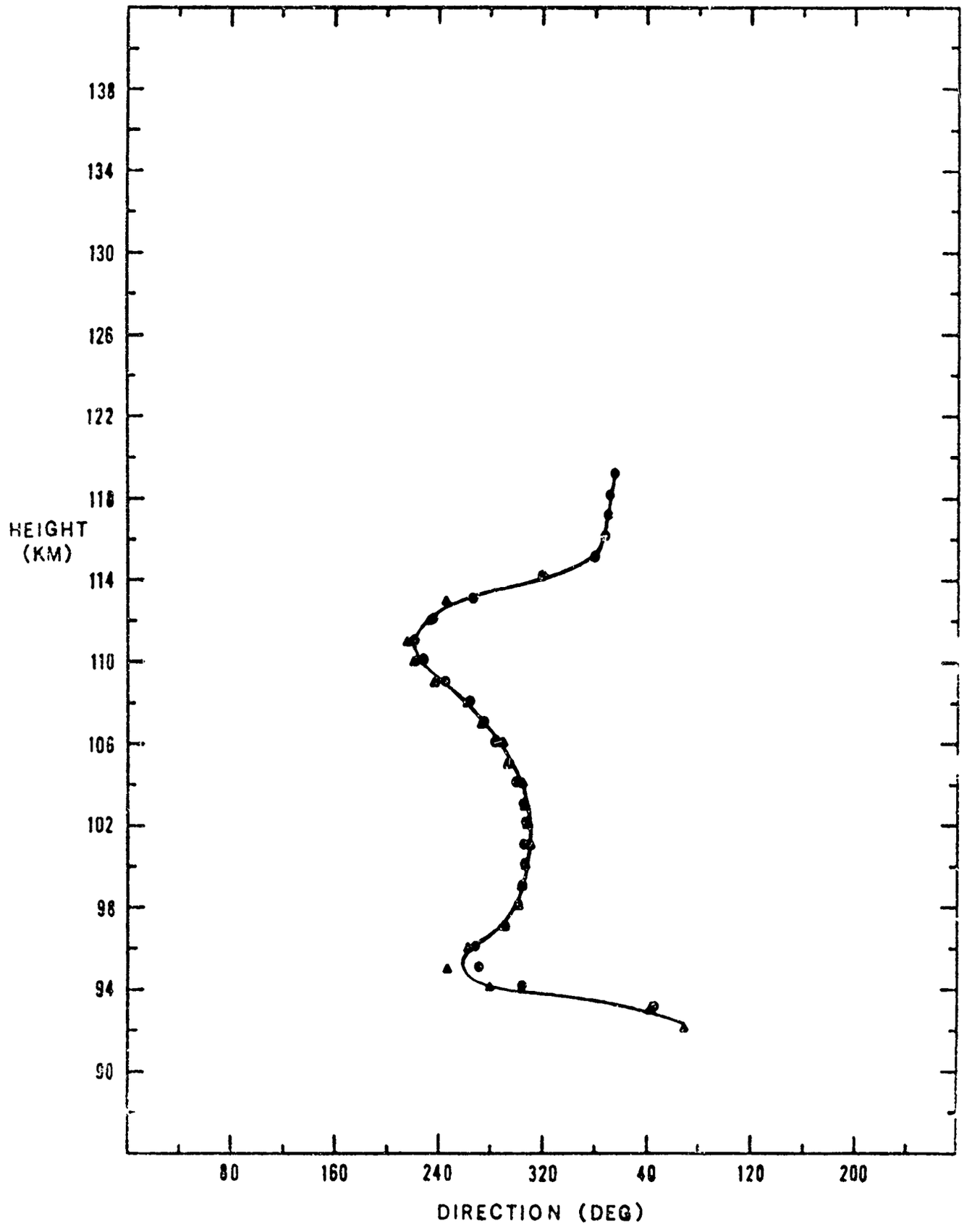
TRAIL NO. 31 CHRIST CHURCH

17 NOVEMBER 1965 18:15:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



TRAIL NO. 32 DOVER

BARBADOS
UP TRAIL

17 NOVEMBER 1965 19-34-00 AST

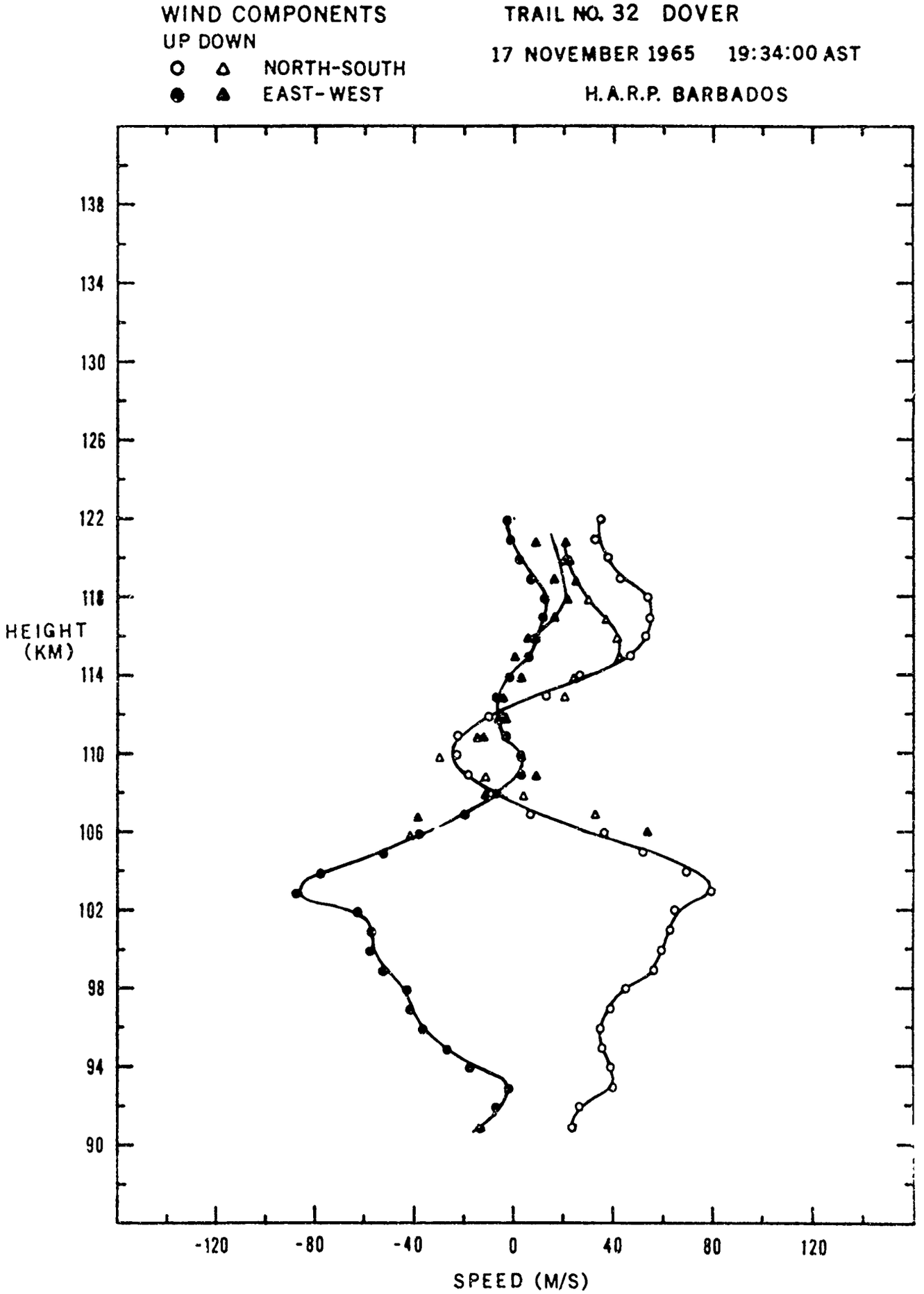
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
91.0	328.9	27.4	23.5	-14.1	25.9	-9.1
92.0	344.8	27.5	26.5	-7.2	27.4	-1.7
93.0	356.9	39.0	39.0	-2.1	38.6	5.8
94.0	334.9	42.3	38.3	-17.9	41.1	-9.8
95.0	323.2	44.6	35.7	-26.7	40.4	-18.9
96.0	313.5	50.6	34.8	-36.7	41.5	-28.9
97.0	312.8	56.9	38.7	-41.8	46.4	-33.1
98.0	316.1	62.5	45.1	-43.3	52.9	-33.3
99.0	317.0	77.4	56.5	-52.8	66.0	-40.3
100.0	315.9	82.5	59.2	-57.5	69.6	-44.3
101.0	317.9	84.9	62.9	-56.9	73.1	-43.0
102.0	315.9	90.4	64.9	-62.9	76.3	-48.5
103.0	312.3	117.7	79.2	-87.1	95.2	-69.3
104.0	311.8	103.7	69.1	-77.3	83.3	-61.7
105.0	314.4	73.7	51.6	-52.7	61.2	-41.2
106.0	312.7	53.0	36.0	-38.9	43.1	-30.8
107.0	288.7	20.7	6.6	-19.6	10.4	-17.9
108.0	216.0	10.5	-8.5	-6.2	-7.1	-7.8
109.0	171.0	19.0	-18.8	3.0	-19.0	-0.9
110.0	172.6	22.7	-22.5	2.9	-22.6	-1.7
111.0	188.5	22.0	-21.8	-3.3	-20.7	-7.6
112.0	203.3	10.5	-9.7	-4.2	-8.7	-6.1
113.0	334.6	15.7	14.1	-6.7	15.2	-3.7
114.0	356.9	27.1	27.0	-1.4	26.7	4.1
115.0	7.3	47.1	46.7	6.0	44.5	15.3
116.0	9.7	54.2	53.4	9.1	50.5	19.7
117.0	12.2	56.1	54.9	11.9	51.4	22.8
118.0	13.9	55.8	54.2	13.4	50.4	24.1
119.0	9.3	44.3	43.7	7.1	41.4	15.8
120.0	4.3	38.2	38.1	2.9	36.7	10.5
121.0	358.7	33.6	33.6	-0.8	33.1	6.0
122.0	356.4	35.9	35.8	-2.2	35.5	5.1

TRAIL NO. 32 DOVER

BARBADOS 17 NOVEMBER 1965 19-34-00 AST

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
106.0	322.5	67.5	53.6	-41.1	60.8	-29.4
107.0	310.8	50.1	32.7	-37.9	39.7	-30.5
108.0	290.9	11.2	4.0	-10.4	6.0	-9.4
109.0	138.9	14.0	-10.5	9.2	-12.1	6.9
110.0	172.2	29.9	-29.6	4.0	-29.8	-2.1
111.0	218.1	18.7	-14.7	-11.6	-12.1	-14.3
112.0	236.3	6.3	-3.5	-5.2	-2.4	-5.8
113.0	347.4	21.3	20.8	-4.7	21.3	-0.4
114.0	7.4	24.5	24.3	3.1	23.2	7.9
115.0	1.3	42.5	42.5	0.9	41.4	9.5
116.0	8.3	41.6	41.2	6.0	39.1	14.2
117.0	24.1	40.9	37.3	16.7	33.2	23.9
118.0	35.2	36.8	30.1	21.2	25.2	26.8
119.0	32.9	30.2	25.4	16.4	21.6	21.2
120.0	48.2	30.7	20.5	22.9	15.4	26.6
121.0	23.8	23.3	21.3	9.4	19.0	13.5


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 32 DOVER
17 NOVEMBER 1965 19:34:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

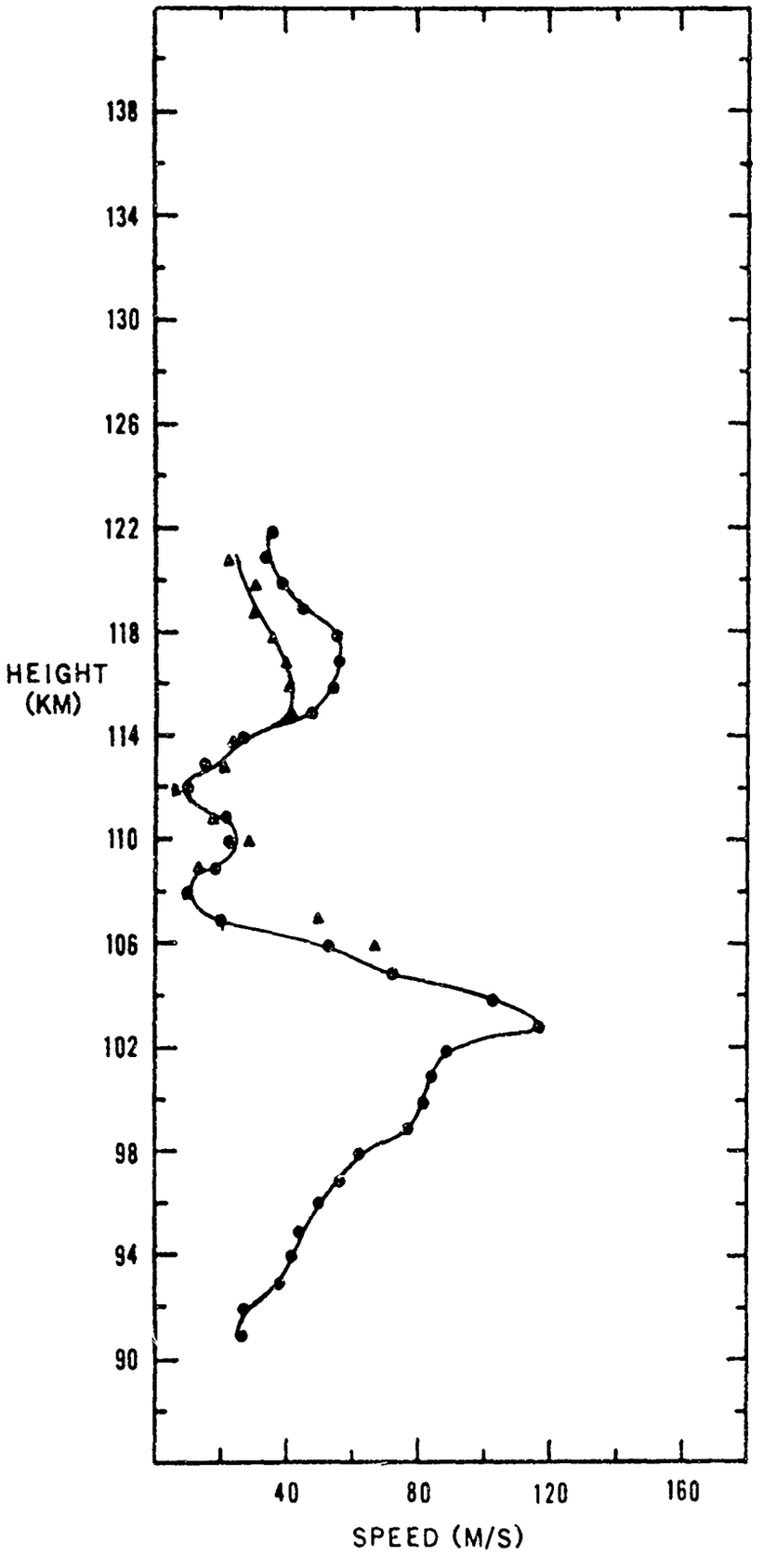
TRAIL NO. 32 DOVER

17 NOVEMBER 1965 19:34:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



WIND DIRECTION

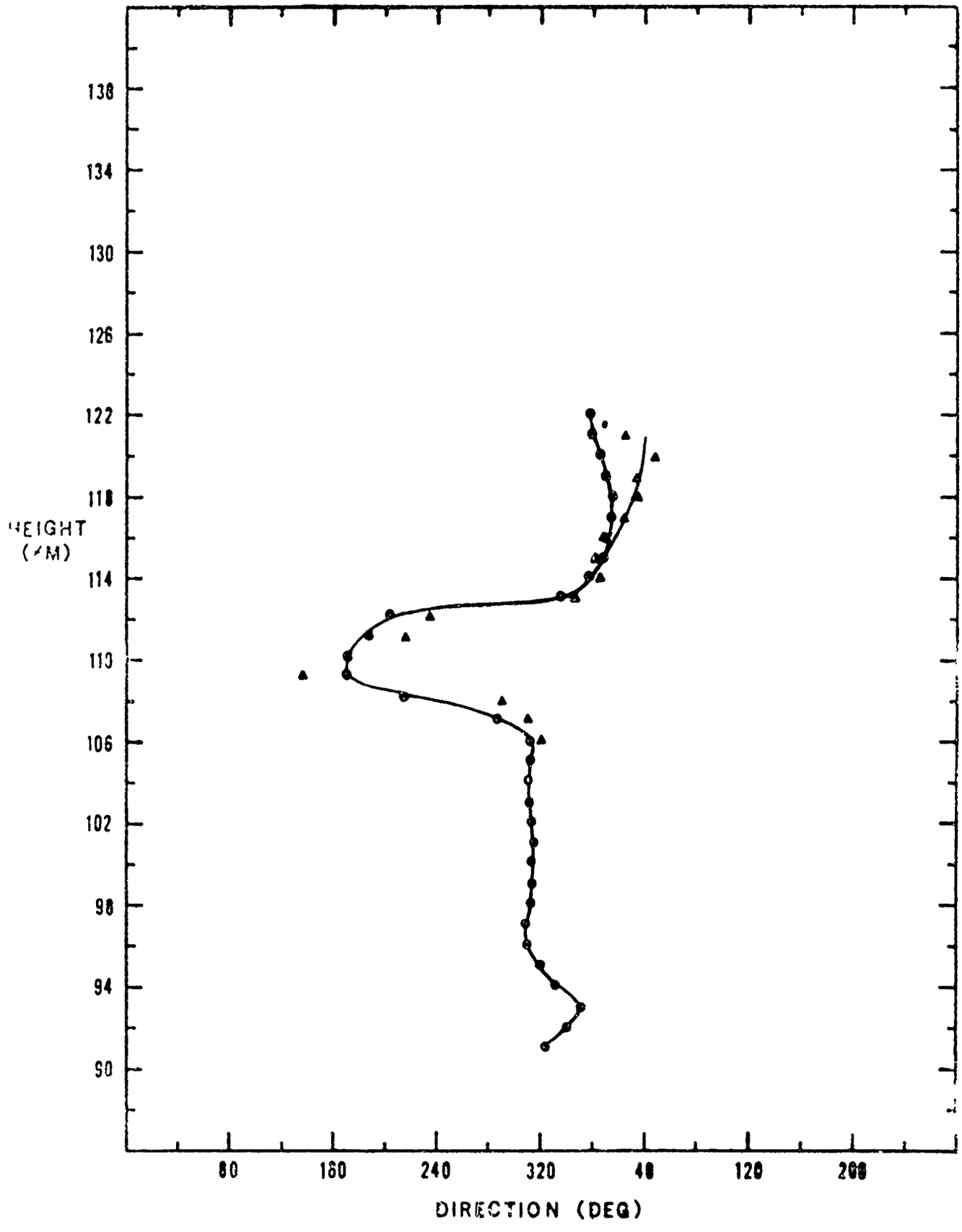
TRAIL NO. 32 DOVER

17 NOVEMBER 1965 19:34:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



TRAIL NO. 33 FOUL BAY

BARBADOS 17 NOVEMBER 1965 23-15-00 AST

UP TRAIL

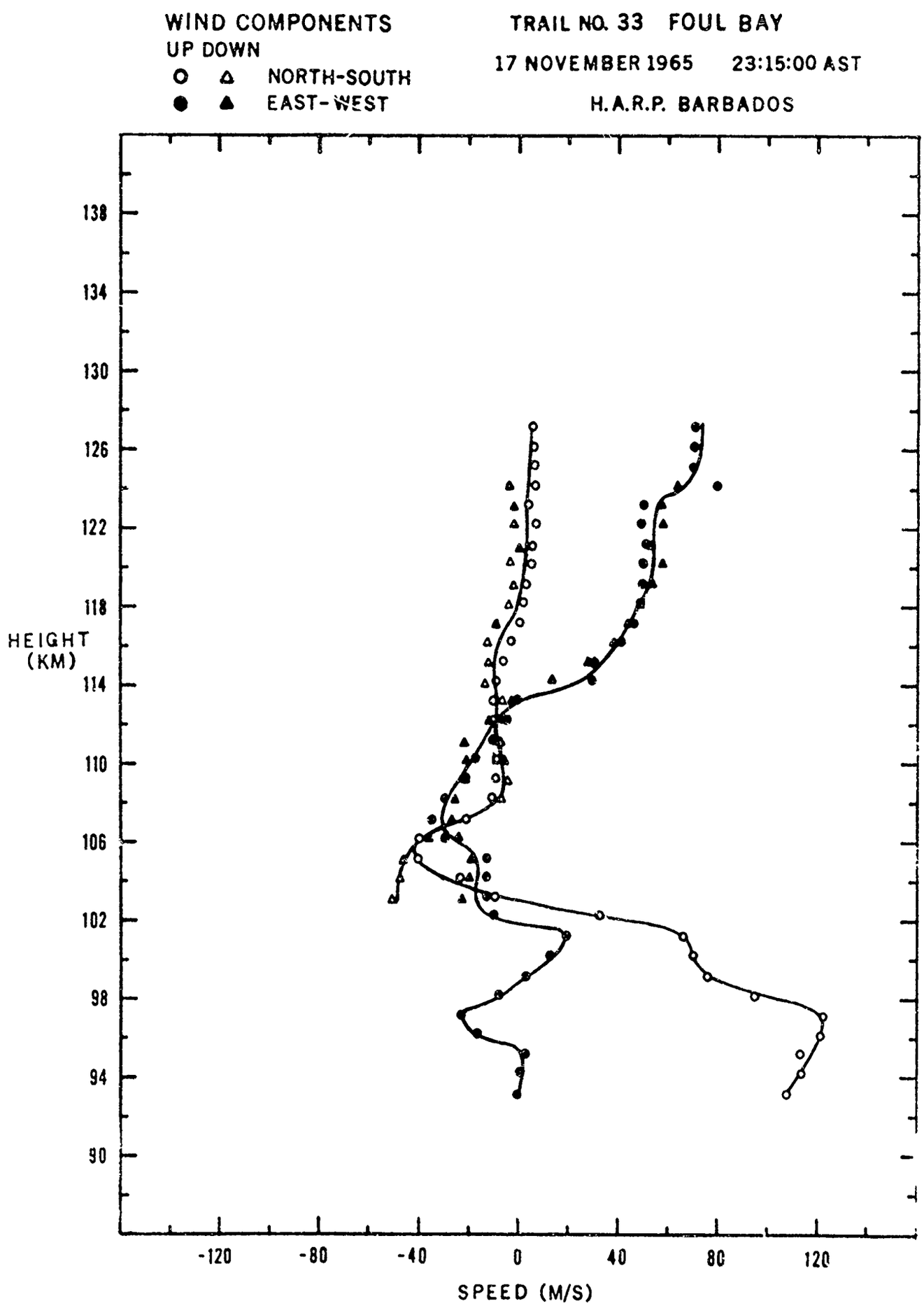
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
93.0	359.4	108.0	108.0	-1.1	106.0	20.8
94.0	0.6	114.7	114.7	1.3	112.1	24.5
95.0	1.5	113.7	113.6	2.9	110.7	25.8
96.0	352.1	122.7	121.6	-16.9	122.5	8.0
97.0	349.2	125.2	123.0	-23.5	125.2	1.9
98.0	355.4	95.4	95.1	-7.6	94.7	11.8
99.0	2.4	76.6	76.5	3.2	74.3	18.6
100.0	9.8	71.4	70.3	12.2	66.4	26.2
101.0	16.1	69.5	66.6	19.3	61.5	32.4
102.0	341.9	35.2	33.5	-10.9	35.0	-3.9
103.0	235.4	16.3	-9.3	-13.4	-6.4	-15.0
104.0	209.4	26.9	-23.4	-13.2	-20.2	-17.7
105.0	197.6	42.6	-40.6	-12.9	-37.2	-20.8
106.0	216.4	49.3	-39.6	-29.2	-32.9	-36.6
107.0	238.8	40.0	-20.7	-34.2	-13.4	-37.7
108.0	250.2	31.6	-10.7	-29.7	-4.5	-31.3
109.0	249.2	23.4	-8.3	-21.9	-3.7	-23.1
110.0	243.6	19.6	-8.7	-17.6	-5.0	-19.0
111.0	214.7	16.2	-8.6	-9.6	-6.5	-11.1
112.0	203.1	10.6	-9.8	-4.2	-8.7	-6.1
113.0	178.3	10.0	-10.0	0.4	-9.9	-1.6
114.0	105.5	31.9	-8.5	30.7	-14.5	28.3
115.0	101.0	31.5	-6.0	31.0	-12.1	29.1
116.0	93.3	41.7	-2.4	41.7	-10.8	40.4
117.0	89.9	46.7	0.1	46.7	-9.3	45.8
118.0	87.5	49.8	2.2	49.7	-7.9	49.1
119.0	85.7	50.6	3.8	50.5	-6.5	50.2
120.0	83.1	50.4	6.0	50.1	-4.3	50.3
121.0	83.0	51.5	6.2	51.1	-4.3	51.3
122.0	81.5	50.1	7.4	49.6	-2.8	50.1
123.0	84.8	50.7	4.6	50.5	-5.7	50.4
124.0	84.8	80.1	7.3	79.8	-9.0	79.6
125.0	84.4	71.1	7.0	70.7	-7.4	70.7
126.0	84.7	70.9	6.6	70.6	-7.8	70.5
127.0	86.4	72.0	4.5	71.8	-10.1	71.2

TRAIL NO. 33 FOUL BAY

BARBADOS
DOWN TRAIL

17 NOVEMBER 1965 23-15-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
103.0	203.7	55.1	-50.4	-22.2	-44.9	-31.9
104.0	202.7	51.3	-47.3	-19.8	-42.3	-29.0
105.0	202.1	50.1	-46.4	-18.9	-41.6	-27.9
106.0	214.6	43.2	-35.6	-24.5	-29.9	-31.2
107.0	229.8	34.9	-22.5	-26.7	-16.6	-30.7
108.0	256.0	26.5	-6.4	-25.7	-1.1	-26.5
109.0	258.4	22.0	-4.4	-21.5	0.0	-21.9
110.0	255.2	22.1	-5.7	-21.4	-1.3	-22.1
111.0	251.4	22.3	-7.1	-21.1	-2.7	-22.1
112.0	242.1	14.0	-6.3	-12.4	-4.0	-13.5
113.0	201.0	7.2	-6.7	-2.6	-6.0	-3.9
114.0	137.5	18.4	-13.6	12.4	-15.8	9.4
115.0	112.8	31.0	-12.0	28.6	-17.5	25.6
116.0	107.8	40.1	-12.3	38.2	-19.8	34.9
117.0	100.5	45.7	-8.4	44.9	-17.3	42.3
118.0	94.6	49.9	-4.0	49.7	-14.0	47.9
119.0	91.1	54.8	-1.1	54.8	-12.2	53.4
120.0	92.4	58.3	-2.5	58.2	-14.2	56.5
121.0	89.9	54.0	0.1	54.0	-10.8	52.9
122.0	91.4	58.7	-1.4	58.6	-13.2	57.1
123.0	90.6	58.2	-0.6	58.2	-12.4	56.9
124.0	93.0	64.7	-3.3	64.6	-16.3	62.6


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 33 FOUL BAY
17 NOVEMBER 1965 23:15:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

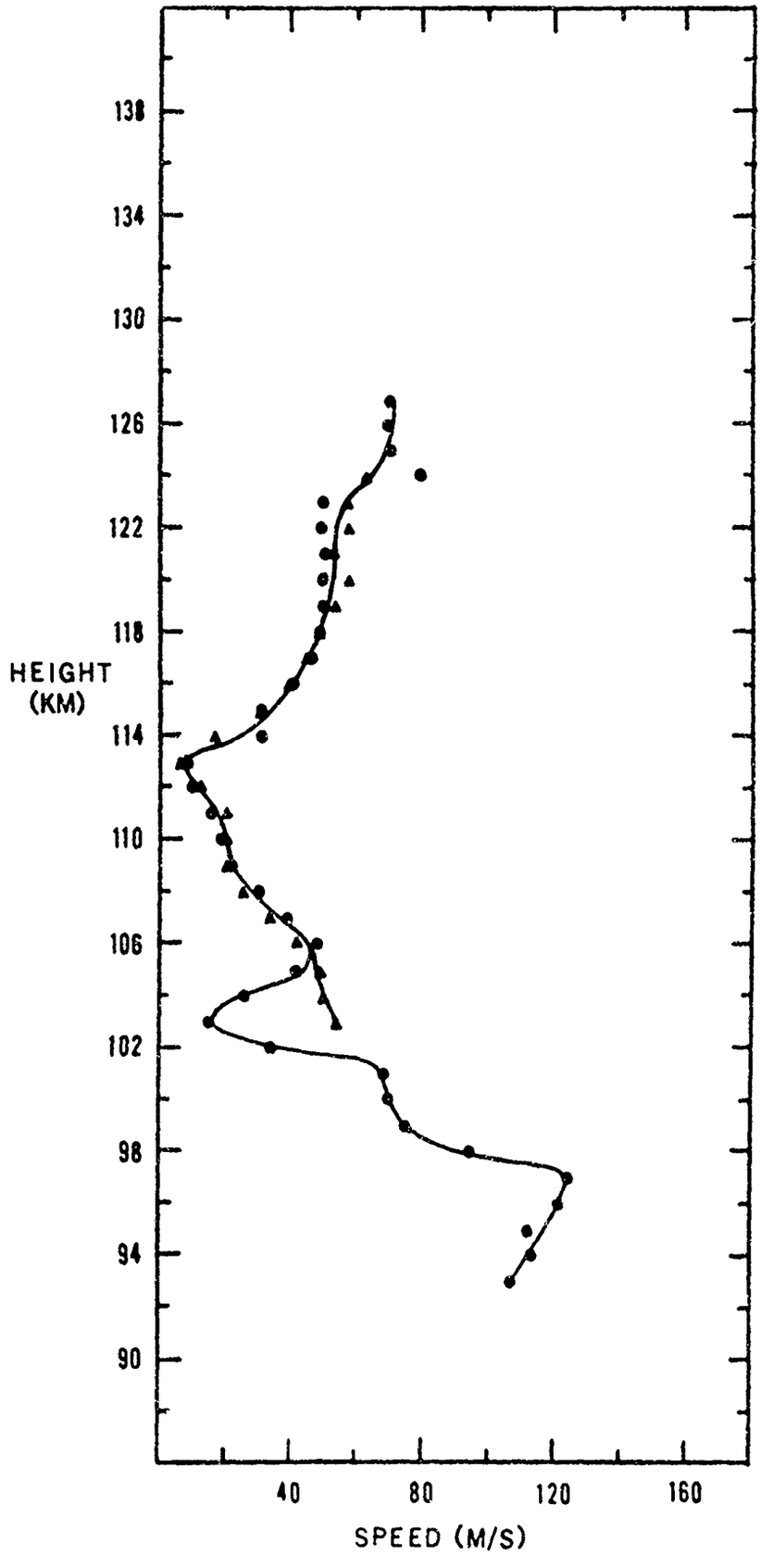
TRAIL NO. 33 FOUL BAY

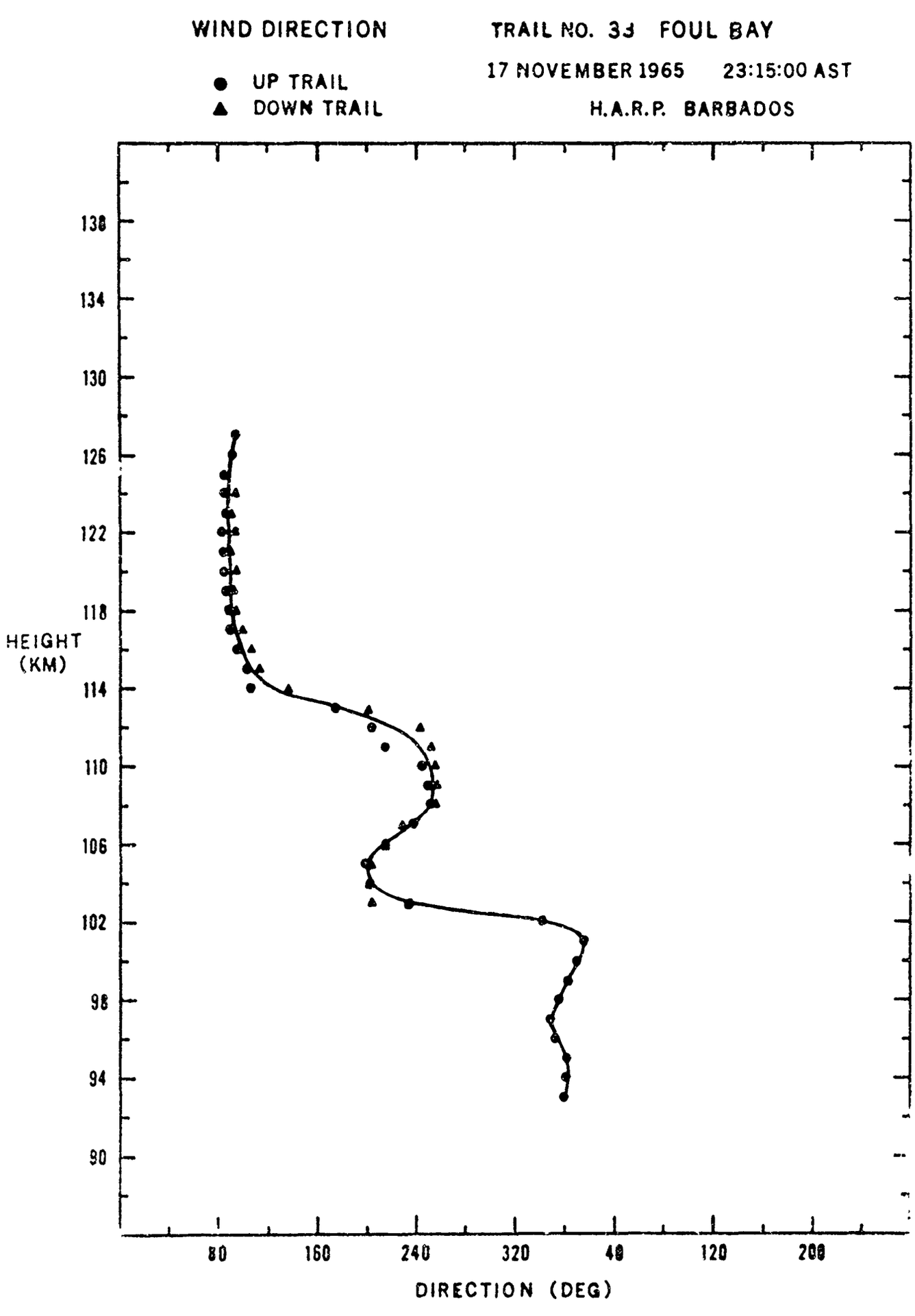
17 NOVEMBER 1965 23:15:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS

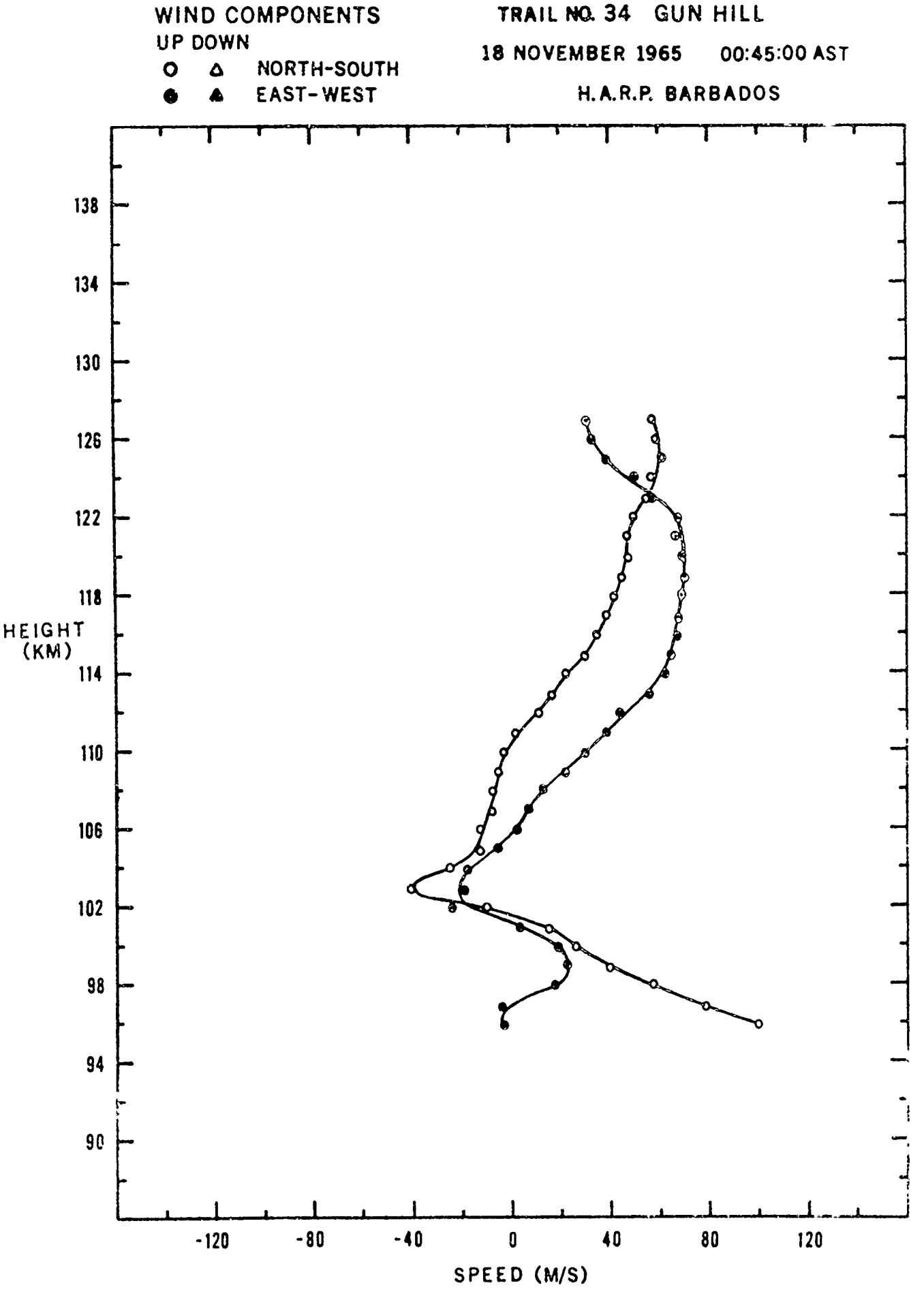



WIND DIRECTION
TRAIL NO. 33 FOUL BAY
17 NOVEMBER 1965 23:15:00 AST
H.A.R.P. BARBADOS
UP TRAIL
DOWN TRAIL
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

TRAIL NO. 34 GUN HILL

BARBADOS 18 NOVEMBER 1965 00-45-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
96.0	358.5	99.8	99.8	-2.7	98.3	17.5
97.0	357.1	78.4	78.3	-3.9	77.5	12.0
98.0	17.0	60.4	57.8	17.6	53.0	28.9
99.0	30.7	46.5	39.9	23.7	34.3	31.3
100.0	36.0	31.6	25.6	18.6	21.3	23.4
101.0	16.1	15.9	15.2	4.4	14.0	7.4
102.0	247.3	26.0	-10.0	-24.0	-4.9	-25.5
103.0	205.0	44.4	-40.2	-18.7	-35.6	-26.4
104.0	216.0	31.0	-25.0	-18.2	-20.8	-22.9
105.0	203.0	13.9	-12.8	-5.4	-11.4	-7.9
106.0	167.2	11.8	-11.5	2.6	-11.8	0.2
107.0	134.2	10.2	-7.1	7.3	-8.4	5.7
108.0	117.4	14.8	-6.8	13.2	-9.3	11.6
109.0	102.2	22.5	-4.8	22.0	-9.1	20.6
110.0	94.2	30.5	-2.3	30.4	-8.4	29.3
111.0	87.6	38.6	1.6	38.6	-6.2	38.1
112.0	76.1	45.5	11.0	44.2	1.8	45.5
113.0	73.9	58.3	16.2	56.0	4.5	58.1
114.0	70.1	65.6	22.4	61.7	9.5	65.0
115.0	65.7	71.2	29.3	64.9	15.6	69.5
116.0	66.0	85.4	34.7	78.0	18.2	83.4
117.0	60.2	77.0	38.3	66.8	24.0	73.2
118.0	58.5	80.6	42.0	68.7	27.2	75.8
119.0	57.3	83.5	45.1	70.3	30.0	78.0
120.0	55.9	83.2	46.6	68.9	31.7	76.9
121.0	54.5	81.9	47.6	66.7	33.1	74.9
122.0	53.3	85.0	50.8	68.1	36.0	77.0
123.0	46.8	80.0	54.8	58.3	41.9	68.2
124.0	41.5	76.2	57.0	50.5	45.6	61.0
125.0	32.3	73.3	61.9	39.2	52.7	50.9
126.0	29.1	67.6	59.1	32.9	51.2	44.2
127.0	28.2	66.2	58.3	31.2	50.8	42.3


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 34 GUN HILL
18 NOVEMBER 1965 00:45:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

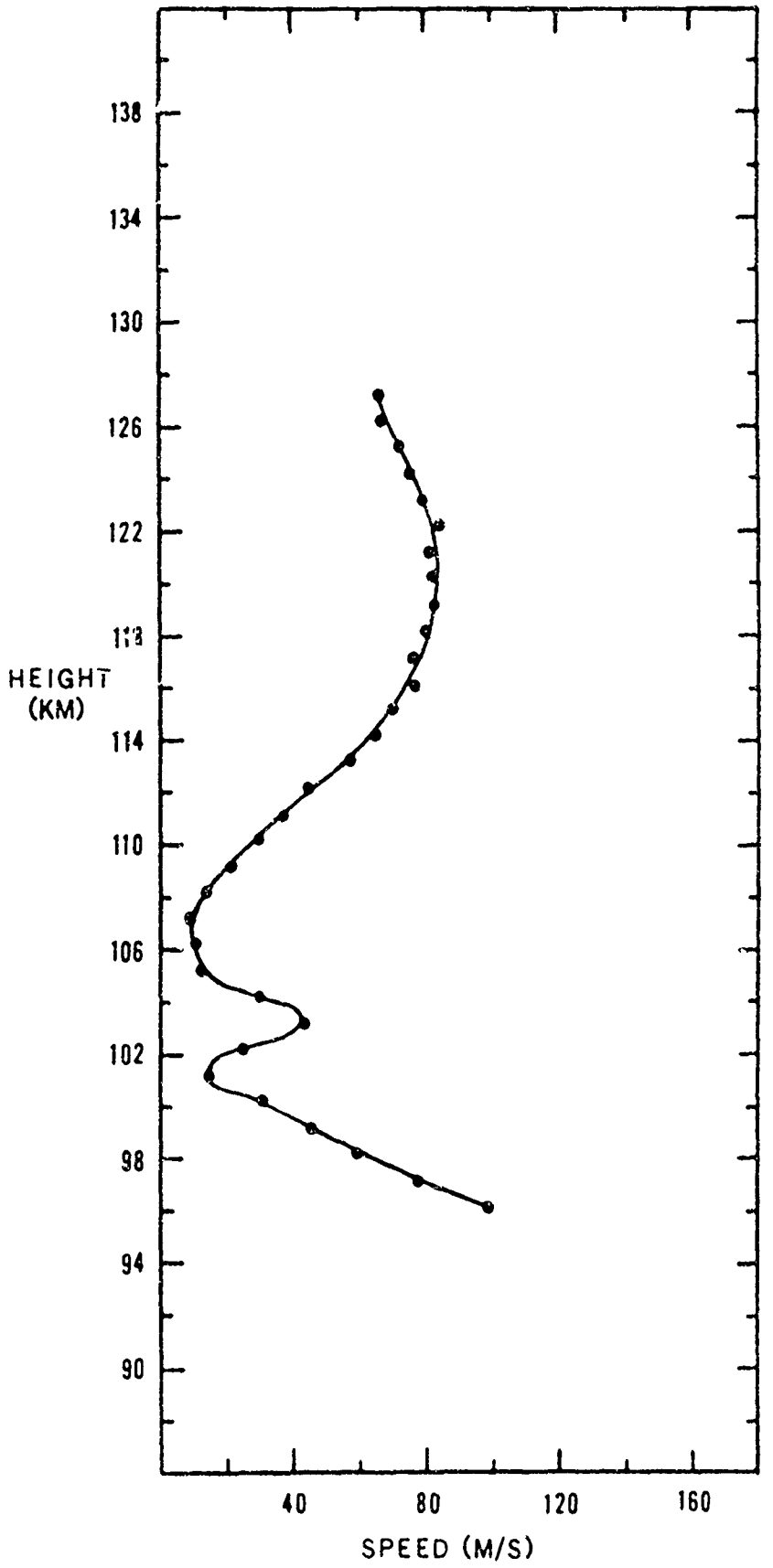
TRAIL NO. 34 GUN HILL

18 NOVEMBER 1965 00:45:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



WIND DIRECTION

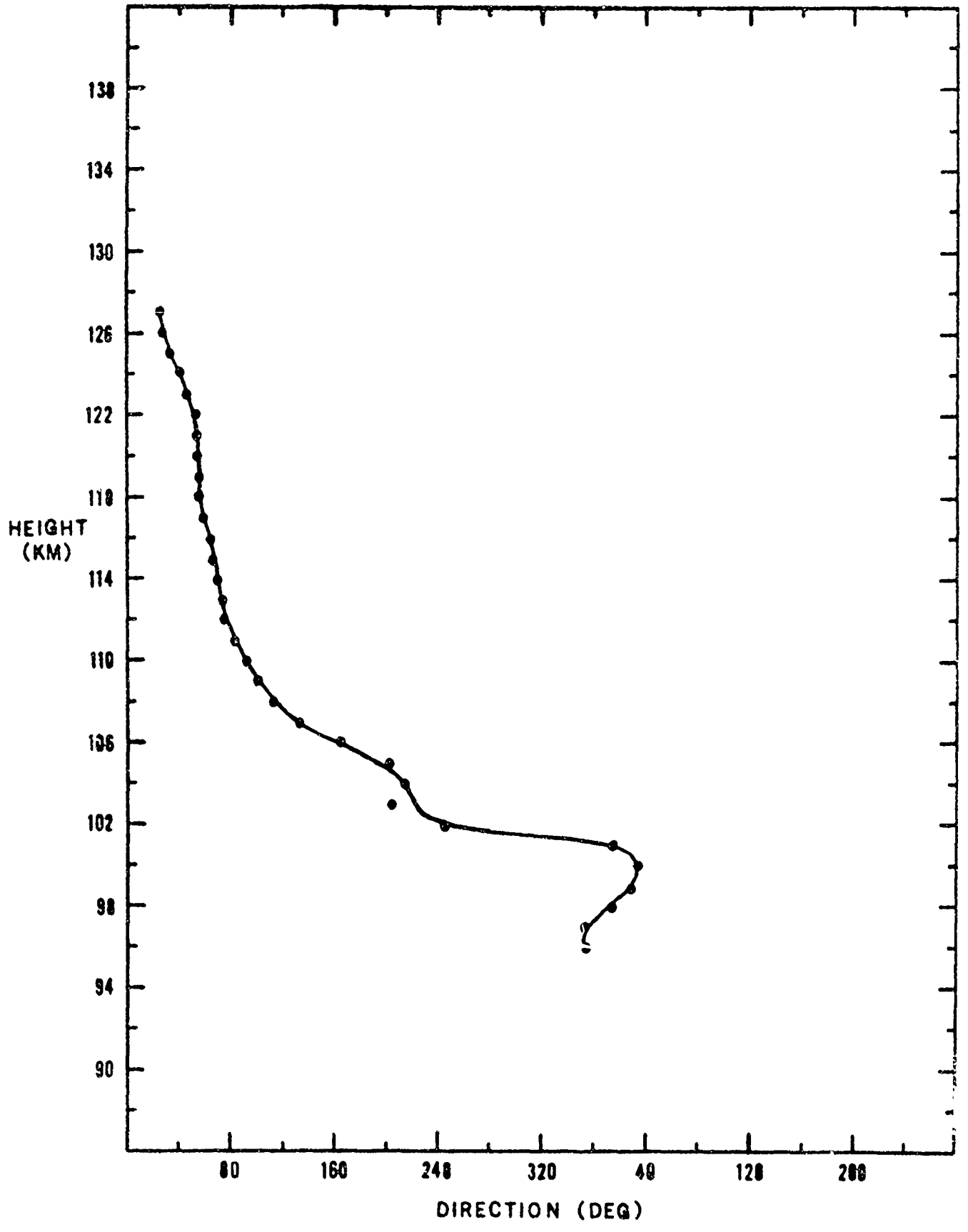
TRAIL NO. 34 GUN HILL

18 NOVEMBER 1965 00:45:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



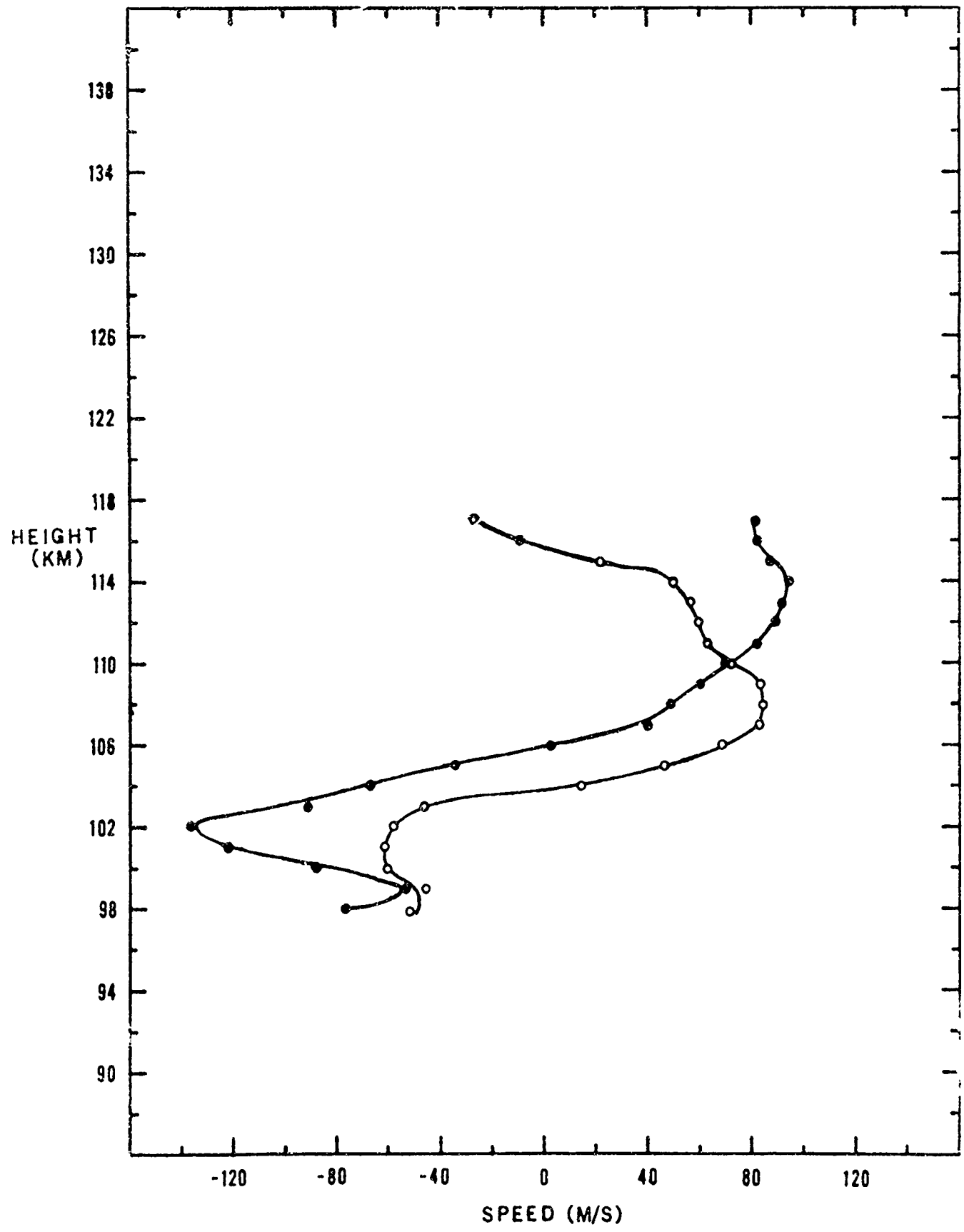
TRAIL NO. 35 INDIAN GROUND

BARBADOS 18 NOVEMBER 1965 03-30-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
98.0	236.0	92.1	-51.5	-76.3	-35.0	-85.1
99.0	229.6	70.8	-45.9	-53.9	-34.1	-62.1
100.0	235.6	106.5	-60.2	-87.8	-41.2	-98.2
101.0	243.1	136.1	-61.7	-121.3	-35.9	-131.3
102.0	246.9	148.1	-58.0	-136.2	-29.3	-145.1
103.0	243.0	101.6	-46.2	-90.8	-26.9	-98.3
104.0	282.5	68.3	14.7	-66.7	27.9	-62.3
105.0	323.6	57.8	46.5	-34.3	52.5	-24.2
106.0	2.3	68.5	68.5	2.7	66.5	16.5
107.0	25.8	92.4	83.2	40.2	73.4	56.2
108.0	30.1	97.4	84.2	48.9	72.6	64.9
109.0	36.2	102.8	83.0	60.8	69.0	76.3
110.0	44.1	100.4	72.1	69.9	55.5	83.0
111.0	52.2	103.7	63.6	81.9	45.7	93.1
112.0	56.2	107.2	59.6	89.1	40.4	99.1
113.0	58.5	107.6	56.3	91.8	36.6	101.3
114.0	62.0	106.5	49.9	94.1	29.8	102.2
115.0	75.9	89.2	21.7	86.5	3.6	89.1
116.0	96.8	82.6	-9.8	82.0	-26.2	78.3
117.0	108.8	85.8	-27.7	81.2	-43.5	73.9

WIND COMPONENTS
UP DOWN
○ △ NORTH-SOUTH
● ▲ EAST-WEST

TRAIL NO. 35 INDIAN GROUND
18 NOVEMBER 1965 03:30:00 AST
H.A.R.P. BARBADOS



WIND SPEED

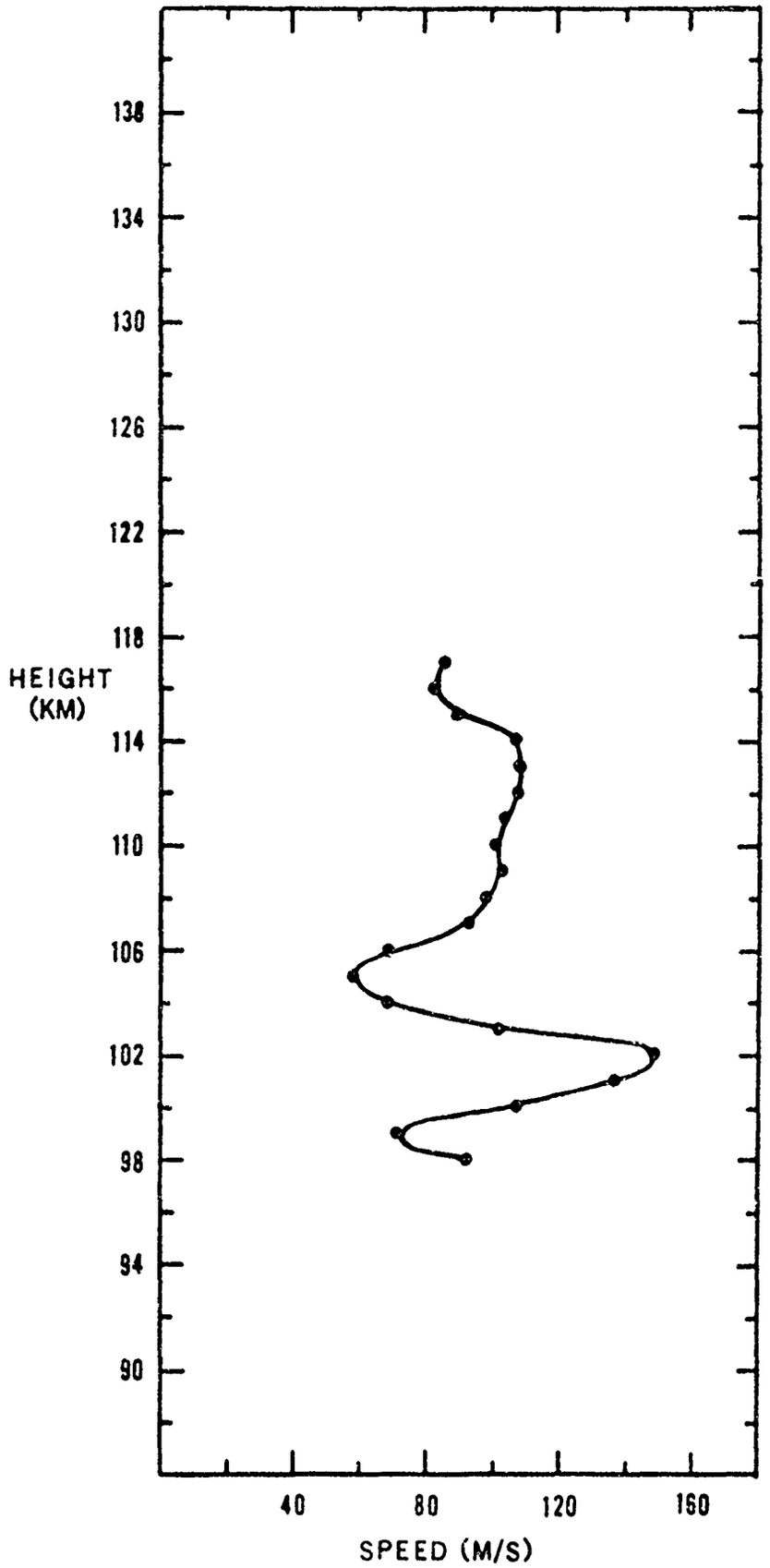
TRAIL NO. 35 INDIAN GROUND

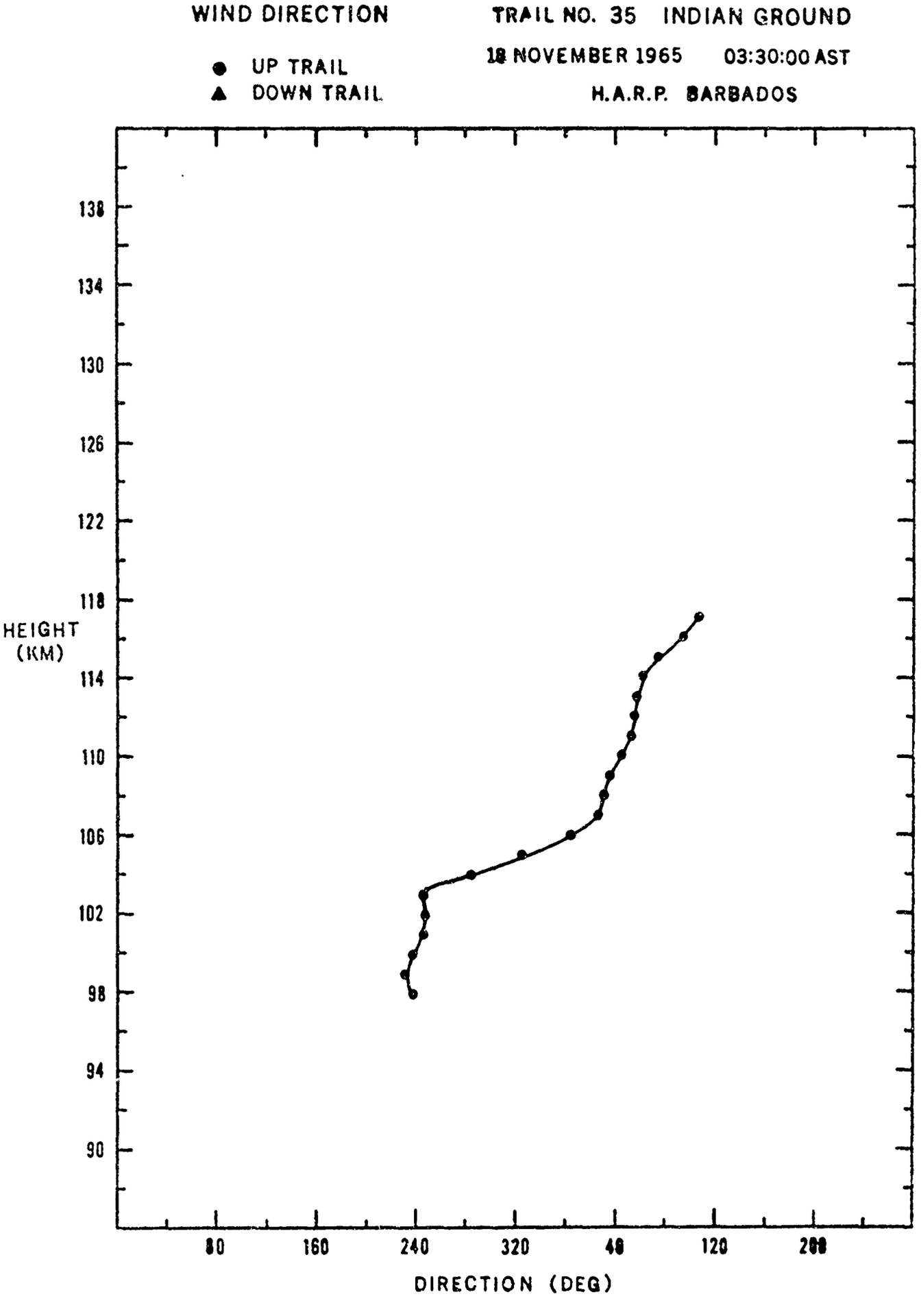
18 NOVEMBER 1965 03:30:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS

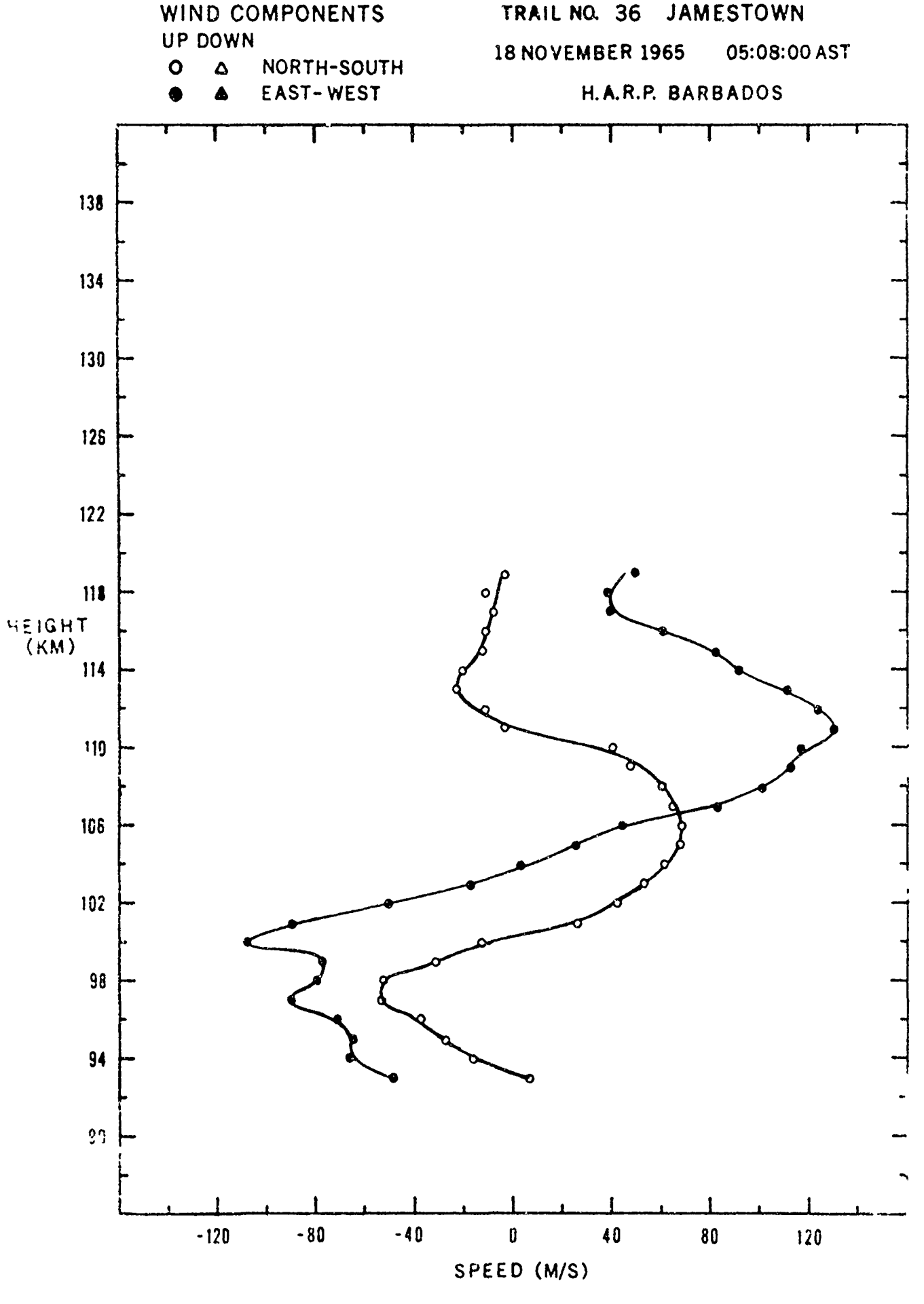



WIND DIRECTION
TRAIL NO. 35 INDIAN GROUND
18 NOVEMBER 1965 03:30:00 AST
H.A.R.P. BARBADOS
UP TRAIL
DOWN TRAIL
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

TRAIL NO. 36 JAMESTOWN

BARBADOS 18 NOVEMBER 1965 05-08-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
93.0	278.0	49.0	6.9	-48.5	16.6	-46.1
94.0	256.3	68.1	-16.2	-66.2	-2.5	-68.1
95.0	247.4	70.4	-27.1	-65.0	-13.4	-69.1
96.0	241.6	80.7	-38.4	-71.0	-23.2	-77.3
97.0	239.4	104.9	-53.4	-90.3	-34.0	-99.2
98.0	236.4	95.3	-52.7	-79.4	-35.6	-88.4
99.0	248.1	83.3	-31.1	-77.3	-14.8	-82.0
100.0	263.4	109.2	-12.5	-108.5	9.7	-108.8
101.0	286.3	93.5	26.3	-89.7	43.9	-82.5
102.0	309.7	65.9	42.1	-50.7	51.5	-41.1
103.0	343.0	56.1	53.6	-16.4	55.8	-5.2
104.0	3.4	61.3	61.2	3.6	59.2	15.9
105.0	20.6	72.8	68.1	25.6	61.5	38.8
106.0	32.9	81.6	68.5	44.4	58.1	57.3
107.0	51.9	105.5	65.0	83.0	46.9	94 .
108.0	59.2	117.7	60.2	101.1	38.5	111.2
109.0	66.9	122.0	47.9	112.3	24.2	119.7
110.0	70.9	123.4	40.4	116.6	16.0	122.4
111.0	91.7	130.5	-3.9	130.4	-30.2	126.9
112.0	95.2	124.5	-11.3	124.0	-36.1	119.2
113.0	101.6	113.9	-22.9	111.6	-45.0	104.7
114.0	102.5	93.9	-20.2	91.7	-38.3	85.7
115.0	98.9	83.5	-12.8	82.5	-29.2	78.2
116.0	100.8	61.5	-11.5	60.4	-23.5	56.8
117.0	101.3	40.2	-7.9	39.4	-15.7	37.0
118.0	106.2	40.3	-11.2	38.7	-18.8	35.6
119.0	94.4	49.5	-3.8	49.3	-13.7	47.5


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 36 JAMESTOWN
18 NOVEMBER 1965 05:08:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

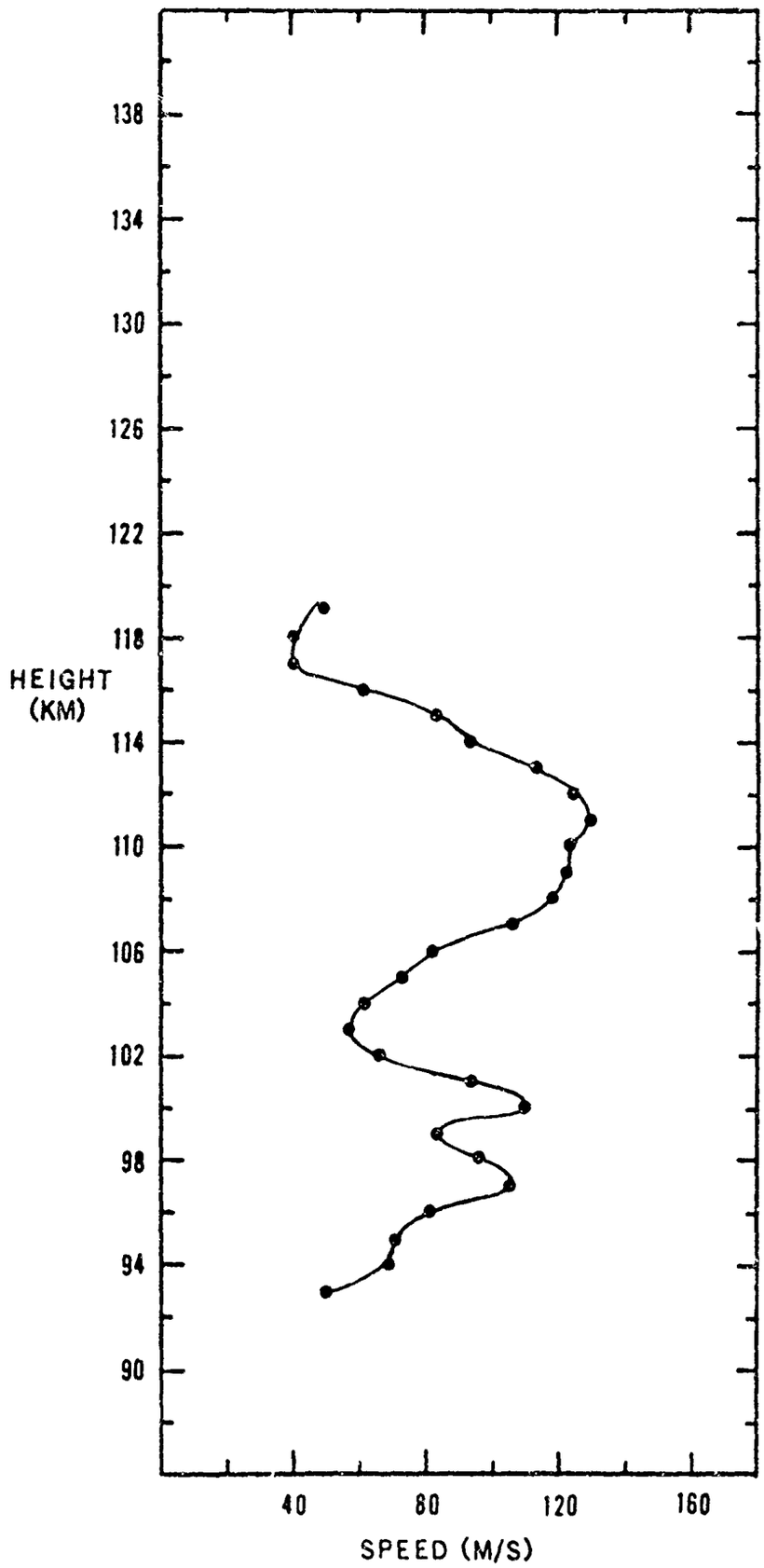
TRAIL NO. 36 JAMESTOWN

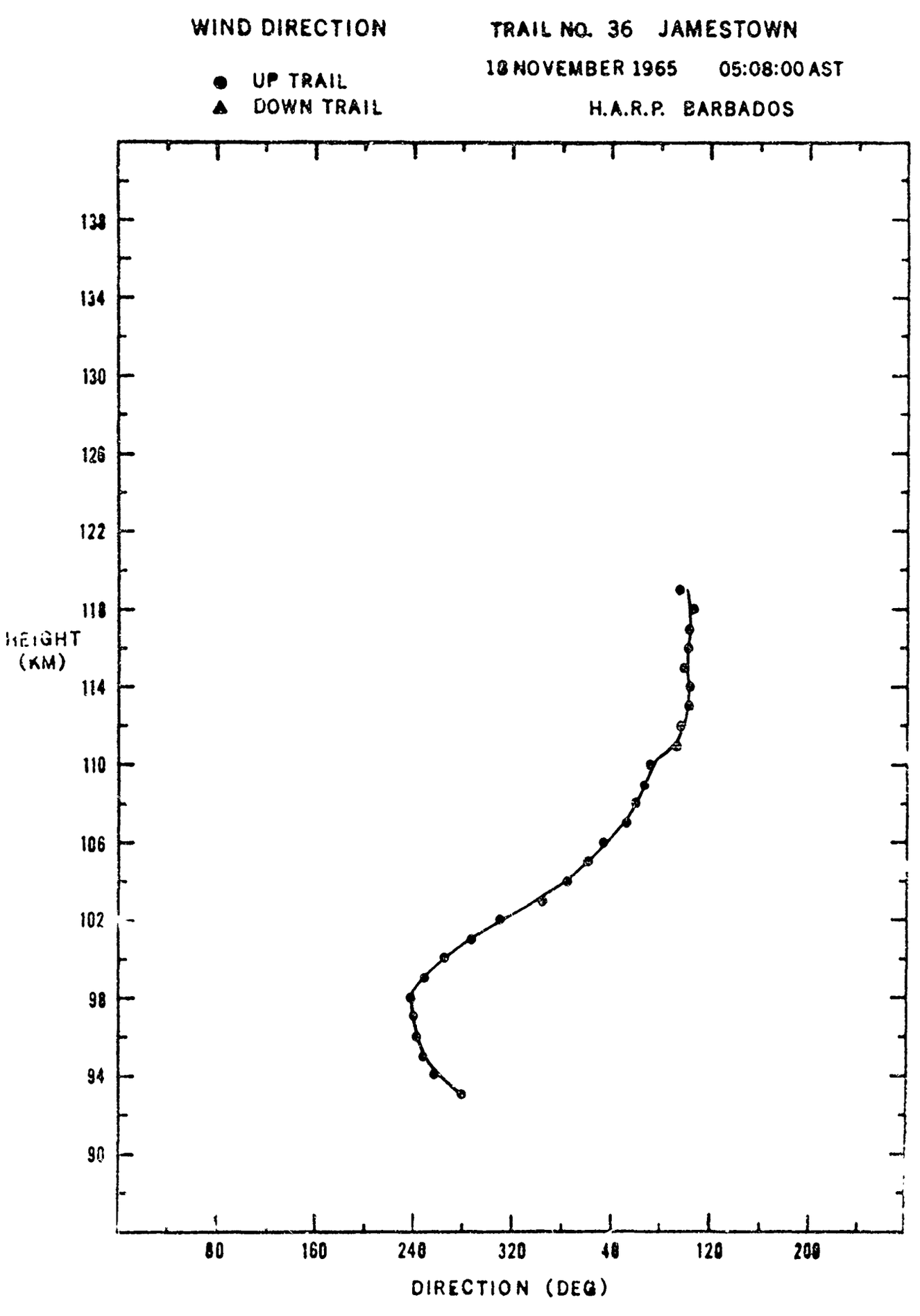
18 NOVEMBER 1965 05:08:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS




WIND DIRECTION
TRAIL NO. 36 JAMESTOWN
18 NOVEMBER 1965 05:08:00 AST
H.A.R.P. BARBADOS
UP TRAIL
DOWN TRAIL
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

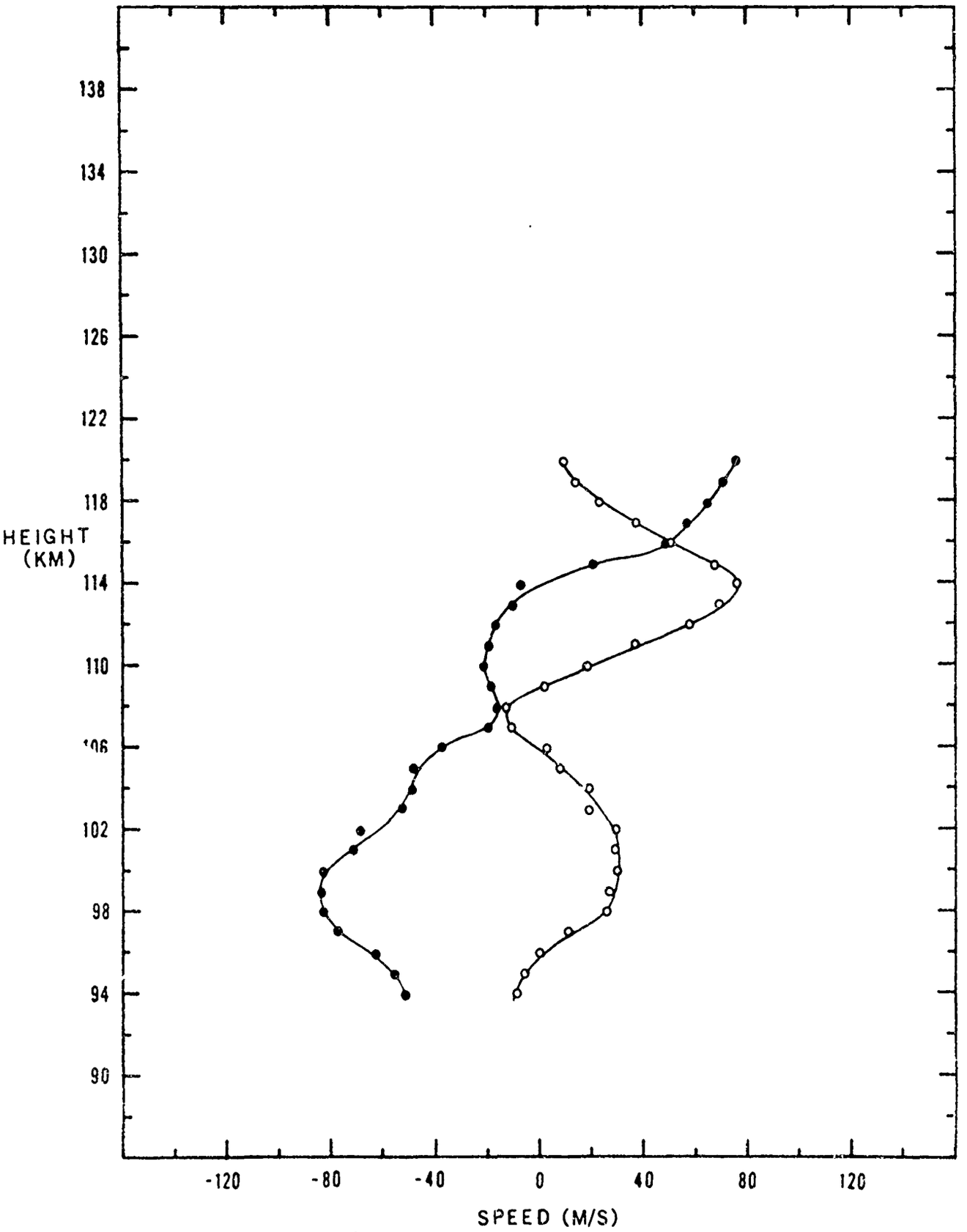
TRAIL NO. 37 MAXWELL

BARBADOS 22 NOVEMBER 1965 18-09-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
94.0	261.4	51.7	-7.8	-51.1	2.7	-51.6
95.0	264.9	55.5	-5.0	-55.2	6.3	-55.1
96.0	270.6	62.7	0.7	-62.6	13.3	-61.2
97.0	278.8	78.3	12.0	-77.4	27.4	-73.4
98.0	287.6	86.6	26.2	-82.6	42.4	-75.6
99.0	288.0	88.3	27.3	-84.0	43.7	-76.7
100.0	290.4	88.6	30.9	-83.0	47.0	-75.0
101.0	292.4	76.4	29.2	-70.7	42.9	-63.3
102.0	293.7	74.8	30.0	-68.5	43.2	-61.0
103.0	290.9	55.7	19.8	-52.1	29.9	-47.0
104.0	292.4	52.5	20.0	-48.6	29.4	-43.6
105.0	280.6	49.3	9.1	-48.5	18.7	-45.7
106.0	275.5	37.5	3.6	-37.3	11.1	-35.8
107.0	242.7	21.4	-9.8	-19.0	-5.8	-20.6
108.0	232.8	20.4	-12.3	-16.2	-8.8	-18.4
109.0	280.1	19.0	3.3	-18.7	7.0	-17.6
110.0	311.5	28.8	19.1	-21.6	23.1	-17.3
111.0	332.9	42.1	37.5	-19.2	40.6	-11.2
112.0	344.2	60.5	58.2	-16.5	60.3	-4.4
113.0	352.5	70.6	70.0	-9.4	70.5	4.9
114.0	355.5	76.8	76.6	-6.1	76.3	9.5
115.0	17.2	72.1	68.8	21.3	63.1	34.8
116.0	43.6	71.1	51.5	49.1	40.5	58.5
117.0	56.7	68.7	37.7	57.4	25.3	63.8
118.0	69.8	69.5	24.0	65.2	10.3	68.7
119.0	78.4	72.6	14.6	71.2	-0.1	72.7
120.0	82.6	76.8	9.9	76.2	-5.7	76.6

WIND COMPONENTS
UP DOWN
○ △ NORTH-SOUTH
● ▲ EAST-WEST

TRAIL NO. 37 MAXWELL
22 NOVEMBER 1965 18:09:00 AST
H.A.R.P. BARBADOS



WIND SPEED

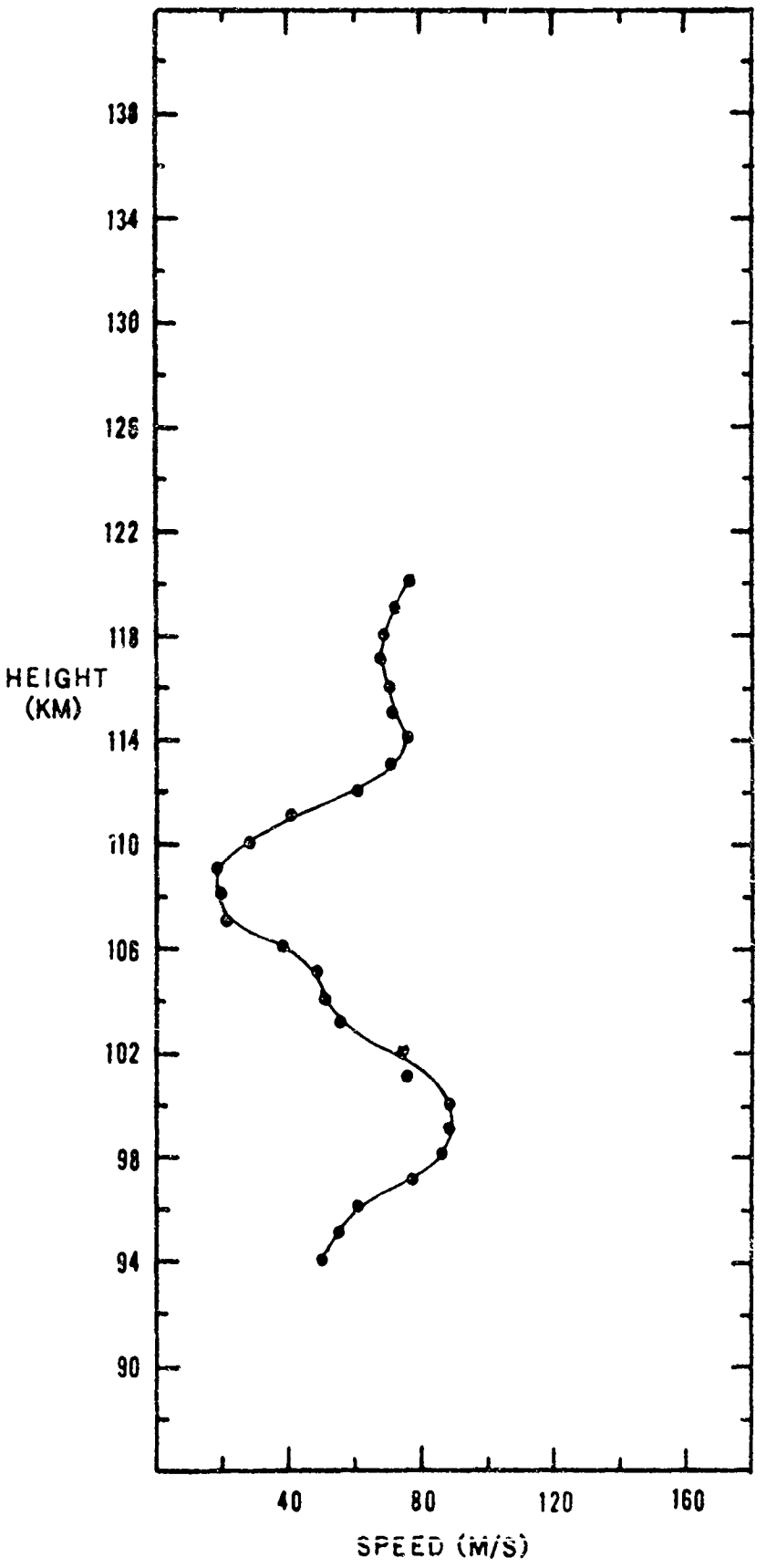
TRAIL NO. 37 MAXWELL

22 NOVEMBER 1965 18:09:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS



WIND DIRECTION

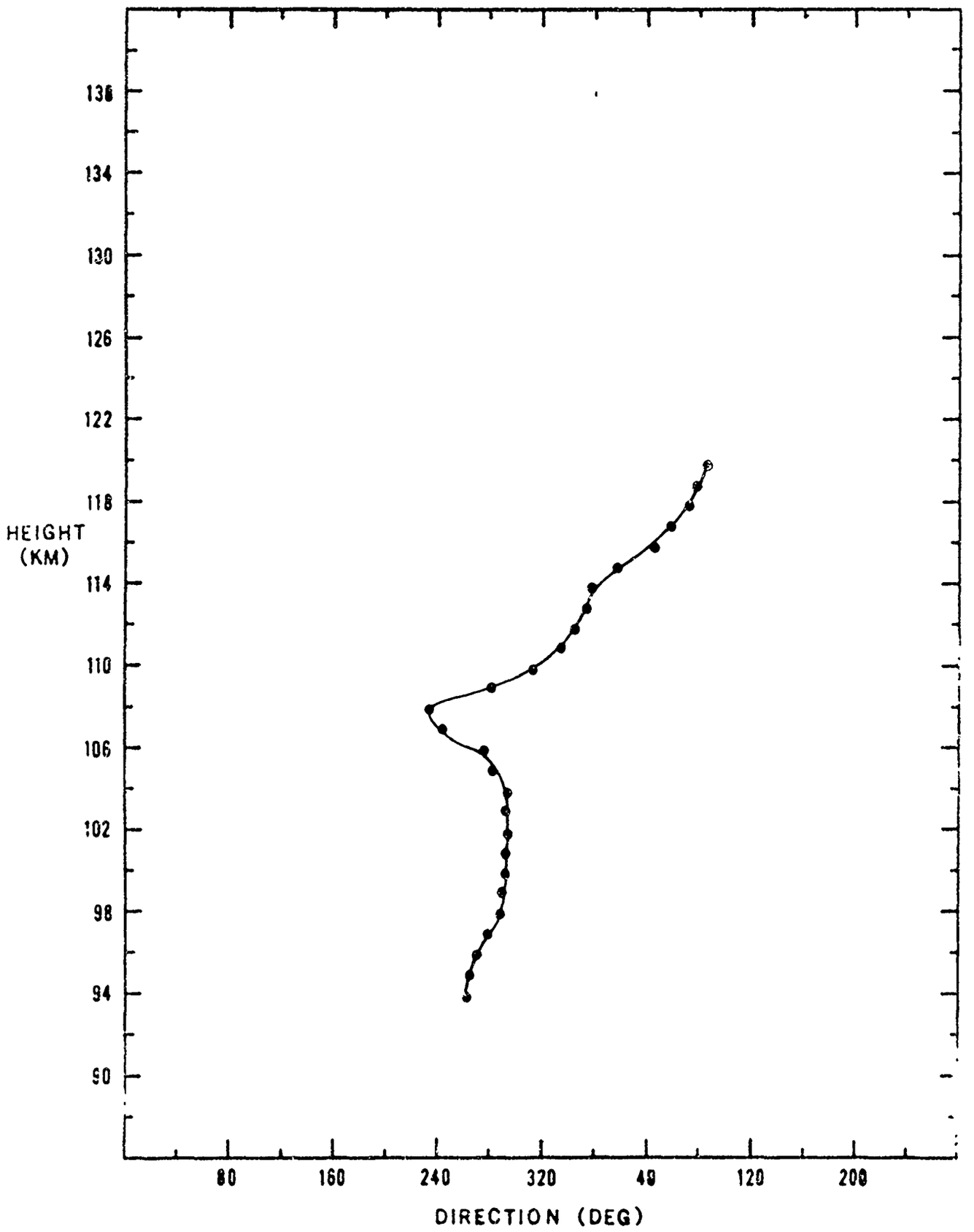
TRAIL NO. 37 MAXWELL

22 NOVEMBER 1965 18:09:00 AST

● UP TRAIL

▲ DOWN TRAIL

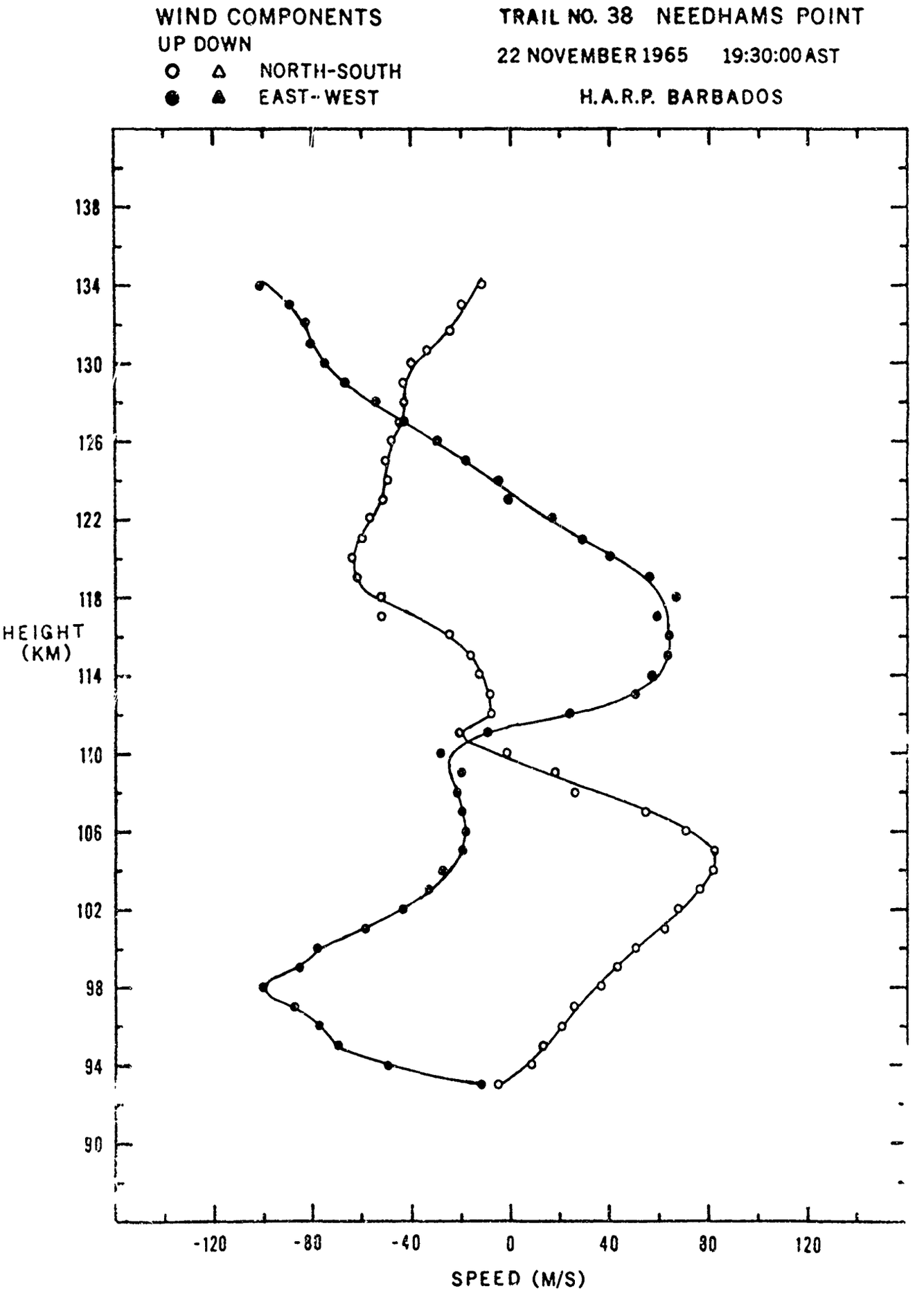
H.A.R.P. BARBADOS



TRAIL NO. 38 NEEDHAM'S POINT

BARBADOS 22 NOVEMBER 1965 19-30-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
93.0	247.4	13.0	-5.0	-12.0	-2.5	-12.8
94.0	279.7	50.7	8.5	-49.9	18.4	-47.2
95.0	281.4	71.4	14.1	-70.0	28.0	-65.7
96.0	285.0	80.4	20.8	-77.6	36.1	-71.8
97.0	286.3	91.2	25.7	-87.5	42.9	-80.5
98.0	289.7	107.1	36.0	-100.9	55.7	-91.5
99.0	296.4	95.6	42.6	-85.6	59.0	-75.2
100.0	302.8	93.2	50.5	-78.4	65.3	-66.6
101.0	316.2	85.4	61.6	-59.1	72.3	-45.4
102.0	326.6	80.4	67.1	-44.3	74.7	-29.8
103.0	336.6	82.9	76.0	-33.0	81.1	-16.9
104.0	341.0	85.7	81.1	-27.9	85.1	-10.9
105.0	346.0	84.0	81.5	-20.3	83.9	-3.4
106.0	345.5	73.0	70.7	-18.2	72.9	-3.5
107.0	339.7	57.9	54.3	-20.1	57.2	-8.7
108.0	319.0	33.8	25.5	-22.2	29.5	-16.6
109.0	310.6	27.1	17.7	-20.6	21.5	-16.6
110.0	266.7	28.2	-1.6	-28.1	4.1	-27.8
111.0	205.6	23.4	-21.1	-10.1	-18.6	-14.2
112.0	109.8	25.0	-8.5	23.5	-13.1	21.3
113.0	100.0	50.6	-8.8	49.9	-18.7	47.1
114.0	103.0	58.2	-13.1	56.7	-24.3	52.9
115.0	104.8	65.0	-16.6	62.9	-29.0	58.2
116.0	112.1	68.5	-25.8	63.5	-38.1	57.0
117.0	132.1	78.6	-52.7	58.3	-63.4	46.4
118.0	128.8	84.6	-53.0	66.0	-65.3	53.9
119.0	138.2	83.9	-62.6	55.9	-72.6	42.1
120.0	148.0	75.1	-64.1	39.1	-70.7	25.3
121.0	155.0	66.7	-60.5	28.2	-65.0	15.4
122.0	164.3	59.3	-57.1	16.0	-59.2	4.1
123.0	182.3	52.4	-52.3	-2.1	-50.8	-12.6
124.0	185.9	50.9	-50.7	-5.2	-48.6	-15.3
125.0	199.9	54.5	-51.2	-18.6	-46.4	-28.6
126.0	212.5	57.0	-48.1	-30.7	-40.9	-39.6
127.0	224.3	62.9	-45.0	-43.9	-35.2	-52.1
128.0	232.2	70.1	-43.0	-55.4	-30.9	-63.0
129.0	236.6	80.4	-44.3	-67.2	-29.8	-74.8
130.0	242.0	85.6	-40.2	-75.6	-24.1	-82.2
131.0	247.2	87.8	-34.0	-81.0	-16.9	-86.2
132.0	253.6	86.9	-24.5	-83.4	-7.1	-86.6
133.0	256.9	91.9	-20.9	-89.5	-2.4	-91.9
134.0	263.3	102.2	-12.0	-101.5	8.8	-101.8


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 38 NEEDHAMS POINT
22 NOVEMBER 1965 19:30:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

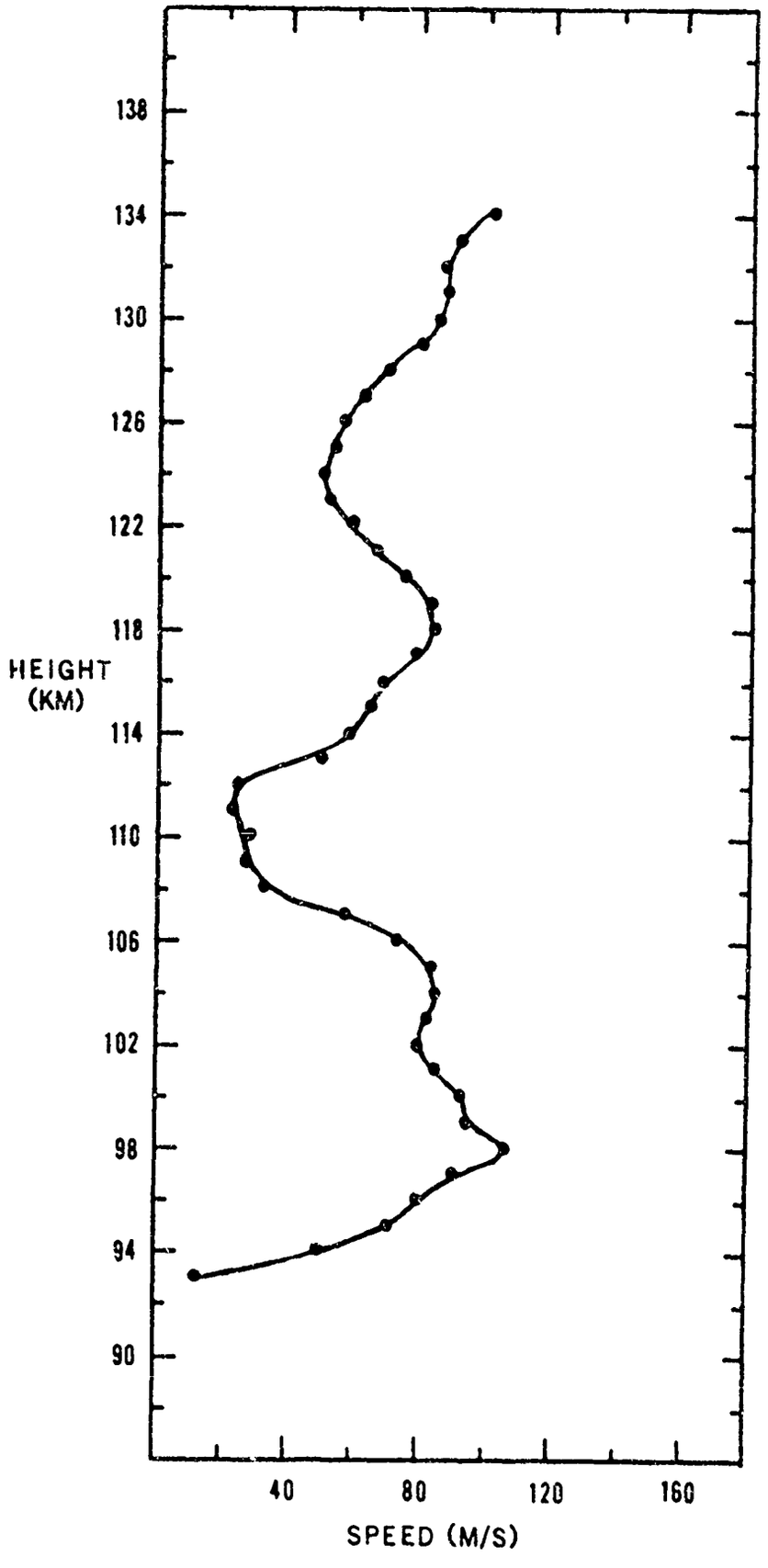
TRAIL NO. 38 NEEDHAMS POINT

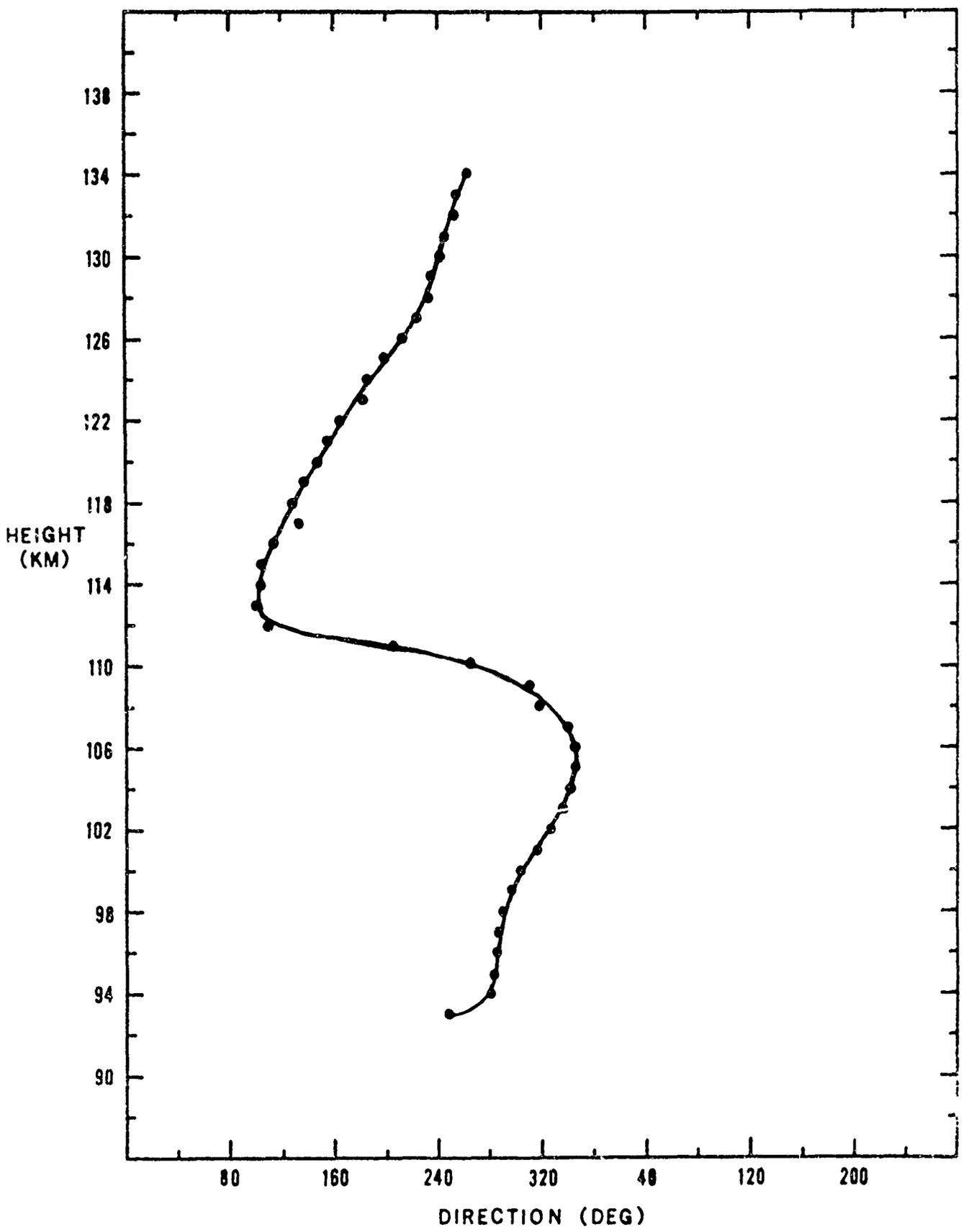
22 NOVEMBER 1965 19:30:00 AST

H.A.R.P. BARBADOS

● UP TRAIL

▲ DOWN TRAIL

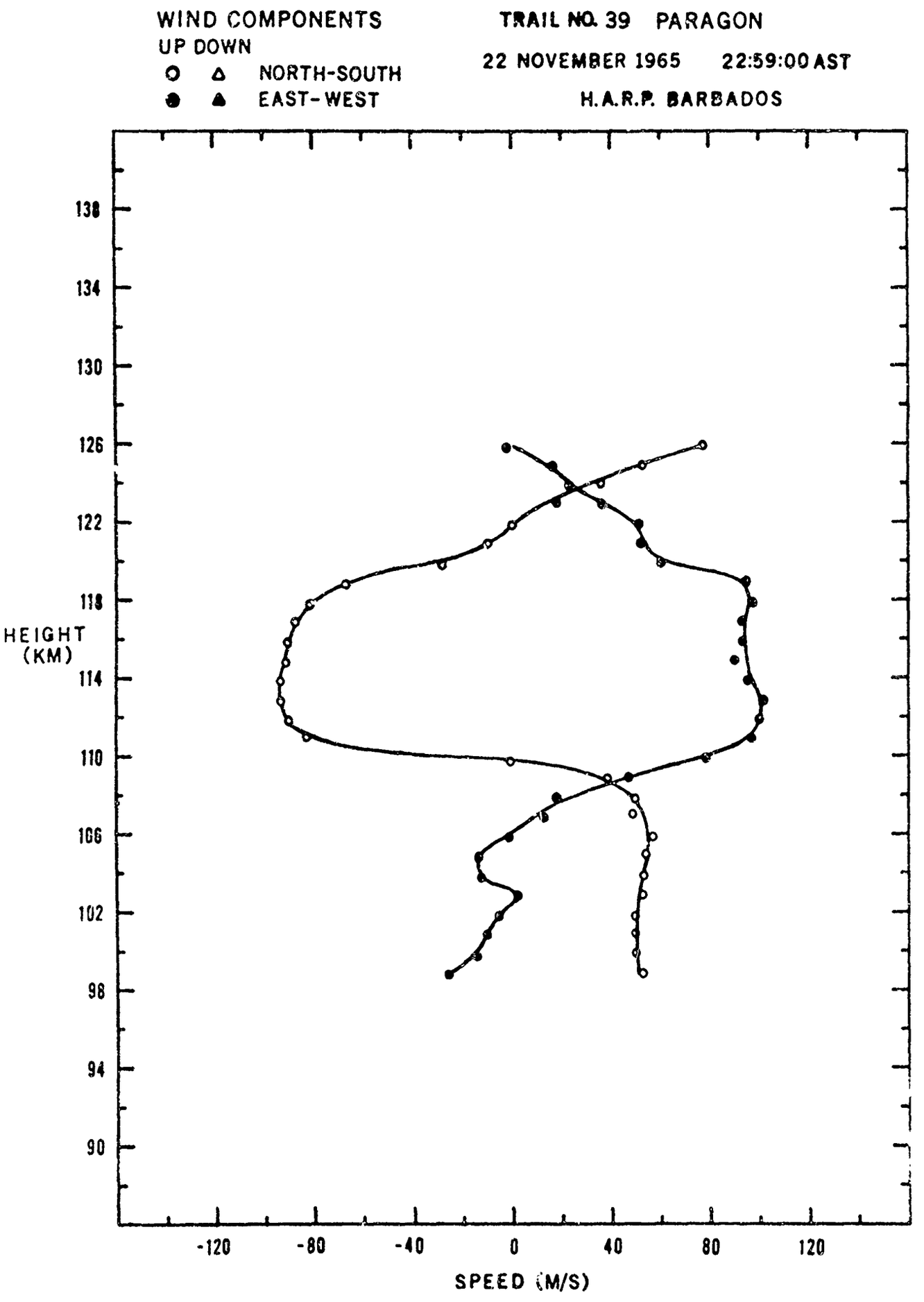



WIND DIRECTION
TRAIL NO. 38 NEEDHAMS POINT
22 NOVEMBER 1965 19:30:00 AST
H.A.R.P. BARBADOS
UP TRAIL
DOWN TRAIL
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

TRAIL NO. 39 PARAGON

BARBADOS 22 NOVEMBER 1965 22-59-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
99.0	334.1	59.0	53.0	-25.8	57.1	-14.5
100.0	344.3	52.9	50.9	-14.3	52.7	-3.7
101.0	349.4	51.6	50.7	-9.5	51.6	0.9
102.0	354.3	50.6	50.3	-5.0	50.3	5.3
103.0	3.3	53.1	53.0	3.0	51.3	13.7
104.0	348.3	55.1	54.0	-11.2	55.1	0.0
105.0	346.8	56.4	54.9	-12.9	56.4	-1.5
106.0	358.7	57.6	57.5	-1.3	56.6	10.4
107.0	15.6	49.9	48.1	13.5	44.4	22.9
108.0	19.9	53.4	50.2	18.2	45.5	28.0
109.0	51.5	60.6	37.7	47.4	27.3	54.0
110.0	90.0	78.7	0.0	78.7	-15.9	77.1
111.0	130.0	126.7	-81.4	97.1	-99.4	78.6
112.0	131.3	133.6	-88.1	100.4	-106.6	80.5
113.0	132.2	137.9	-92.7	102.1	-111.4	81.2
114.0	134.2	133.1	-92.7	95.5	-110.1	74.8
115.0	135.0	129.0	-91.2	91.1	-107.7	70.8
116.0	133.2	130.1	-89.2	94.8	-106.5	74.8
117.0	132.4	128.5	-86.7	94.9	-104.1	75.4
118.0	129.2	126.6	-80.0	98.1	-98.2	79.9
119.0	124.6	116.2	-66.0	95.7	-84.0	80.4
120.0	114.2	66.7	-27.4	60.8	-39.1	54.0
121.0	98.6	54.3	-8.2	53.7	-18.9	50.9
122.0	89.2	53.4	0.8	53.4	-10.0	52.5
123.0	64.8	41.5	17.7	37.5	9.8	40.3
124.0	33.8	44.4	37.0	24.7	31.2	31.7
125.0	18.9	56.7	53.7	18.4	48.9	28.9
126.0	358.8	78.9	78.9	-1.7	77.6	14.3


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 39 PARAGON
22 NOVEMBER 1965 22:59:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

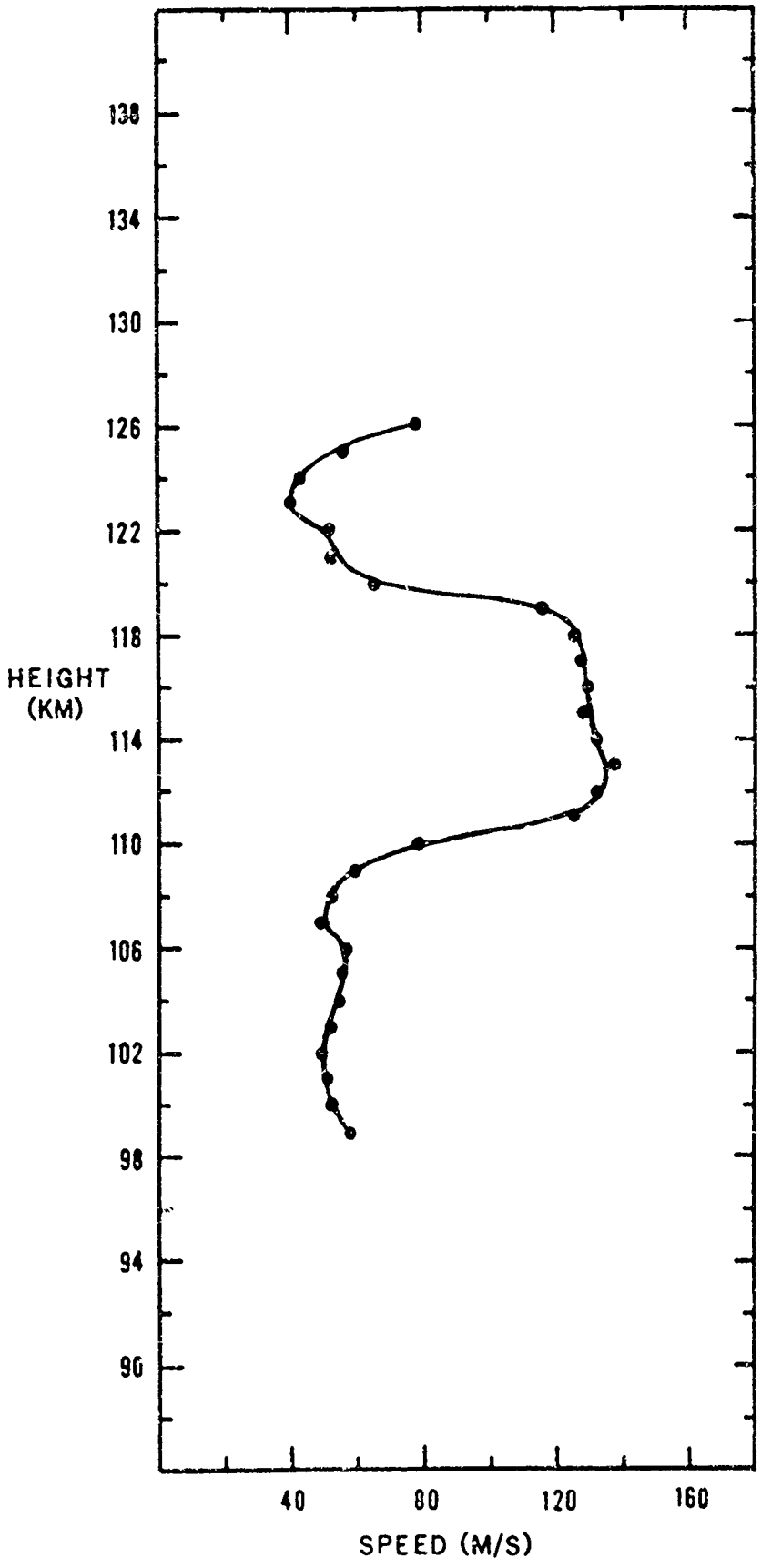
TRAIL NO. 39 PARAGON

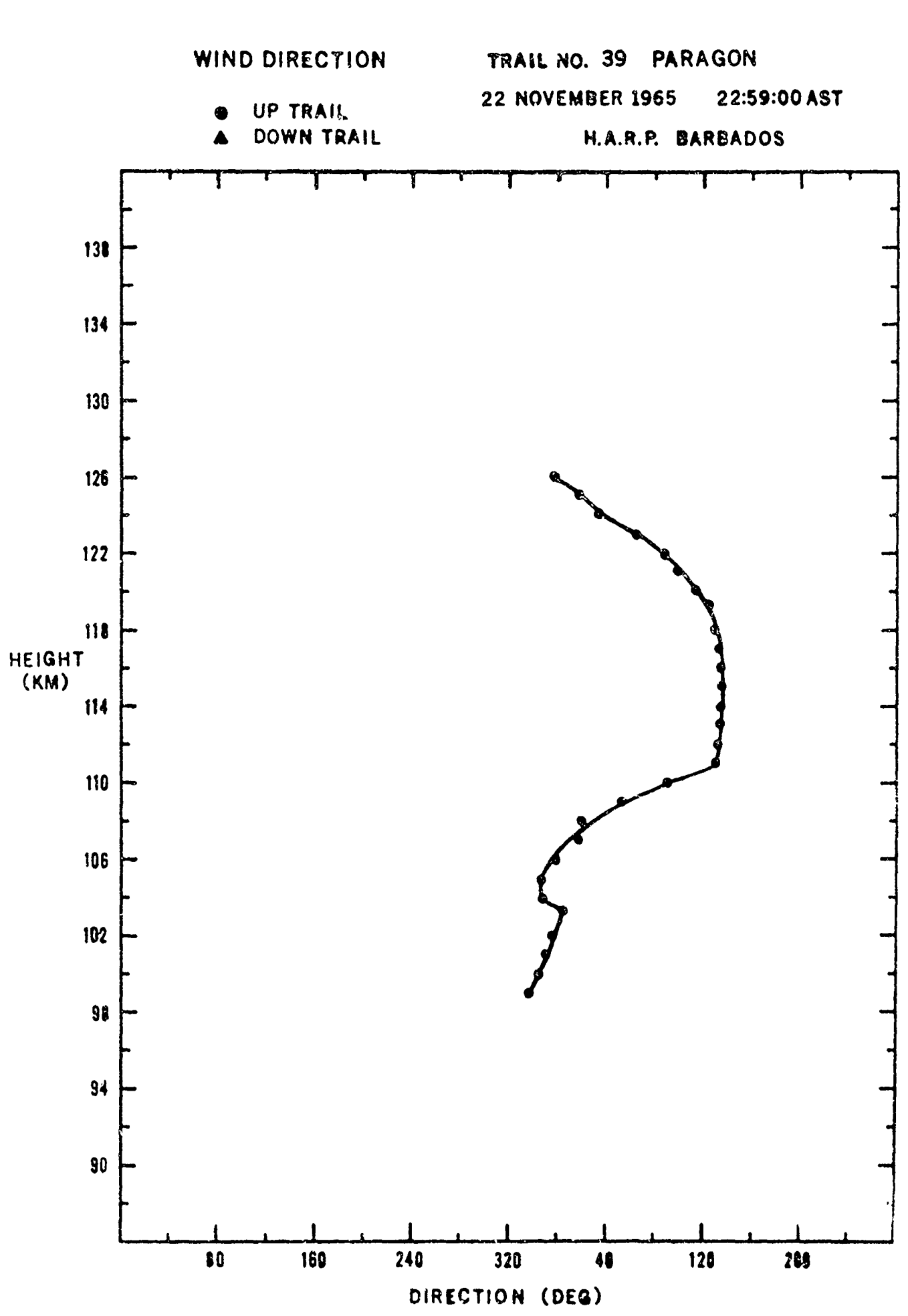
22 NOVEMBER 1965 22:59:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS

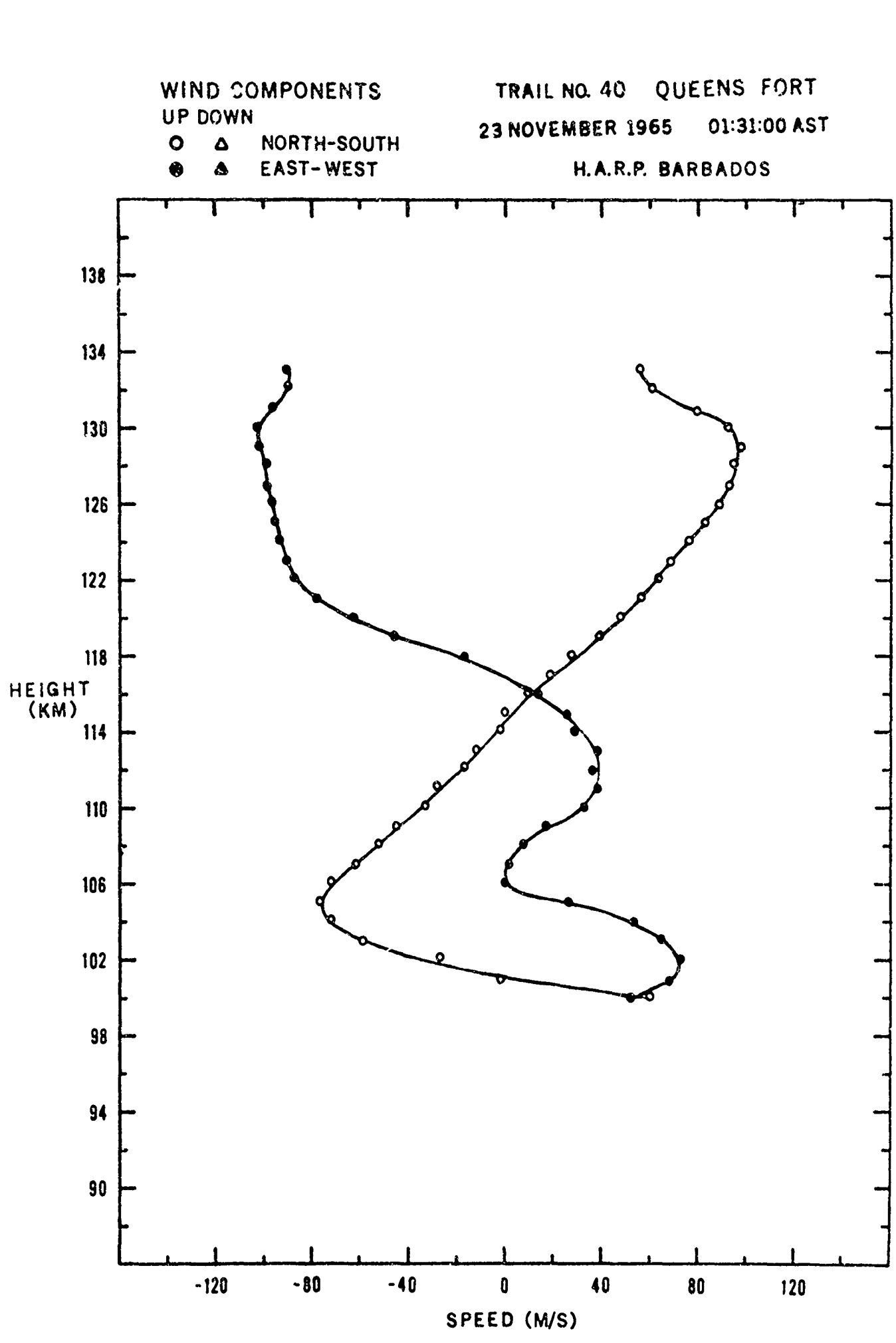



WIND DIRECTION
TRAIL NO. 39 PARAGON
22 NOVEMBER 1965 22:59:00 AST
UP TRAIL
DOWN TRAIL
H.A.R.P. BARBADOS
138
134
130
126
122
118
114
110
106
102
98
94
90
HEIGHT (KM)
80
160
240
320
40
120
200
DIRECTION (DEG)

TRAIL NO. 40 QUEEN S FORT

BARBADOS 23 NOVEMBER 1965 01-31-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
100.0	[illegible]	[illegible]	[illegible]	[illegible]	47.9	62.8
101.0	91.3	[illegible]	[illegible]	[illegible]	[illegible]	66.4
102.0	110.8	76.4	[illegible]	71.5	-41.0	64.5
103.0	132.9	86.9	-59.2	63.6	-70.8	50.3
104.0	144.5	90.3	-73.5	52.4	-82.6	36.5
105.0	161.3	81.6	-77.2	26.2	-80.9	10.0
106.0	180.3	72.4	-72.4	-0.3	-70.8	-14.9
107.0	179.4	63.3	-63.3	0.7	-62.1	-12.1
108.0	172.8	54.2	-53.8	6.8	-54.1	-4.2
109.0	159.4	49.4	-46.3	17.4	-48.9	7.7
110.0	136.3	46.8	-33.8	32.3	-39.6	24.8
111.0	127.8	47.6	-29.2	37.6	-36.2	30.9
112.0	116.8	40.5	-18.3	36.2	-25.2	31.8
113.0	109.8	39.4	-13.4	37.0	-20.6	33.5
114.0	94.6	27.7	-2.2	27.6	-7.7	26.6
115.0	89.1	25.4	0.4	25.4	-4.7	25.0
116.0	55.8	16.2	9.1	13.4	6.2	15.0
117.0	359.2	18.2	18.2	-0.3	17.9	3.4
118.0	325.1	32.1	26.3	-18.4	29.5	-12.7
119.0	310.1	59.6	38.4	-45.6	46.8	-36.9
120.0	306.3	78.8	46.7	-63.5	58.6	-52.7
121.0	304.9	96.4	55.2	-79.1	70.1	-66.3
122.0	305.0	108.5	62.2	-88.8	78.9	-74.4
123.0	306.0	113.9	66.9	-92.2	84.2	-76.8
124.0	308.3	120.8	74.8	-94.9	92.4	-77.8
125.0	310.4	125.4	81.3	-95.5	98.9	-77.1
126.0	311.8	131.5	87.7	-98.0	105.7	-78.2
127.0	313.2	136.4	93.4	-99.5	111.6	-78.6
128.0	313.3	136.7	93.7	-99.5	111.9	-78.5
129.0	313.2	140.8	96.4	-102.6	115.2	-81.0
130.0	311.5	139.2	92.1	-104.3	111.3	-83.5
131.0	309.2	125.1	79.0	-97.0	97.0	-79.0
132.0	303.1	108.9	59.5	-91.2	76.7	-77.3
133.0	300.7	106.8	54.6	-91.8	72.0	-78.9


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 40 QUEENS FORT
23 NOVEMBER 1965 01:31:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

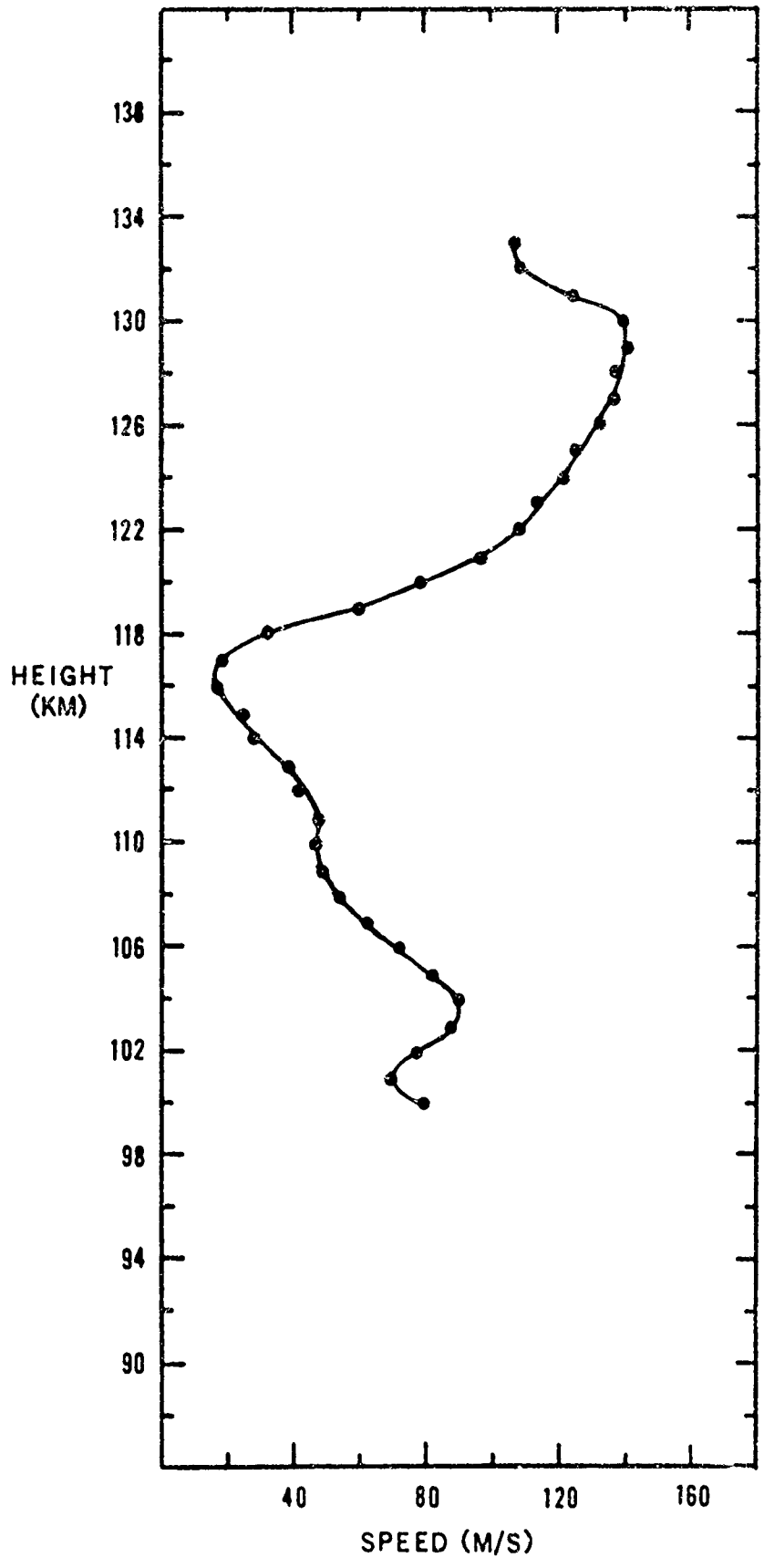
TRAIL NO. 40 QUEENS FORT

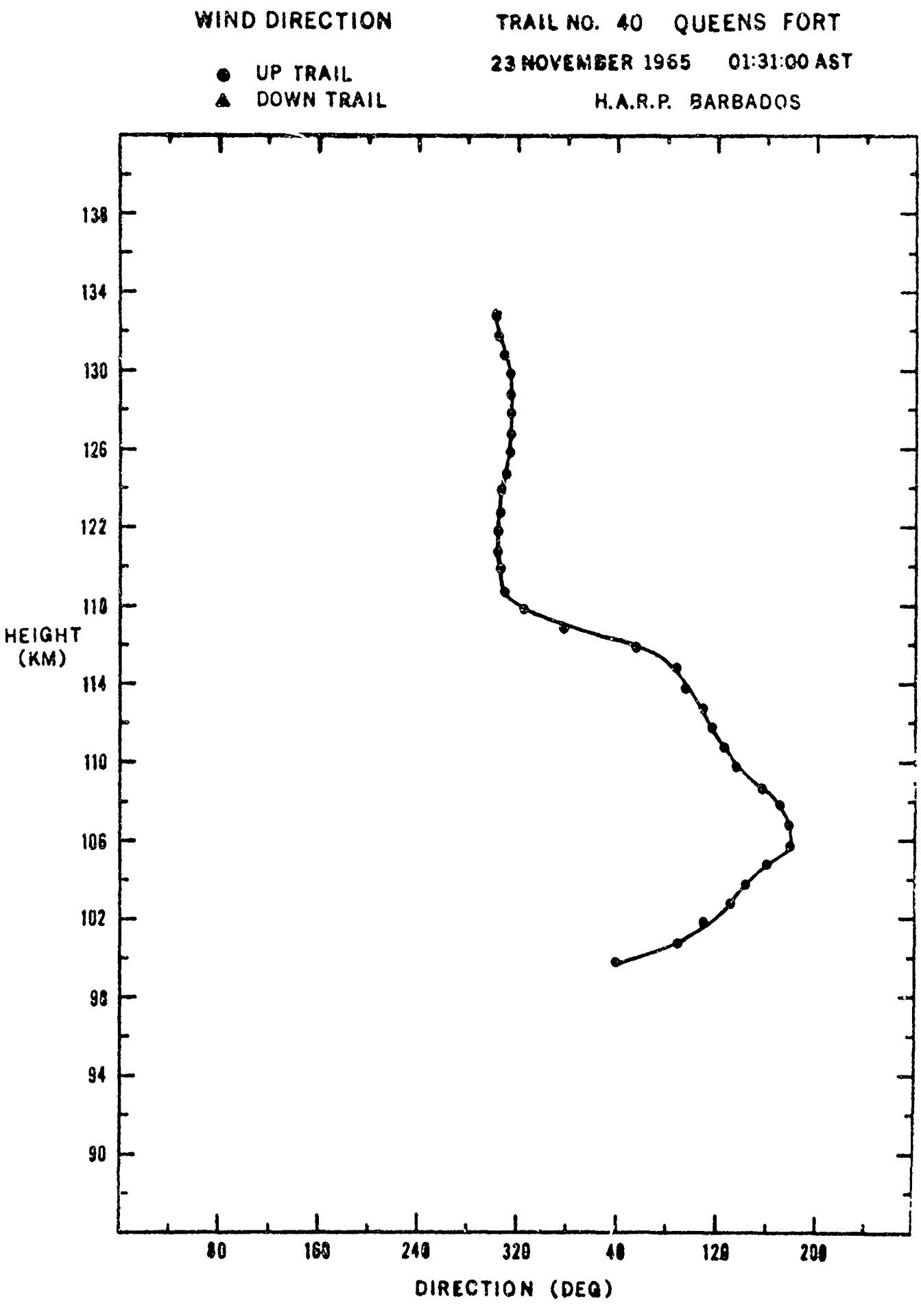
23 NOVEMBER 1965 01:31:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS

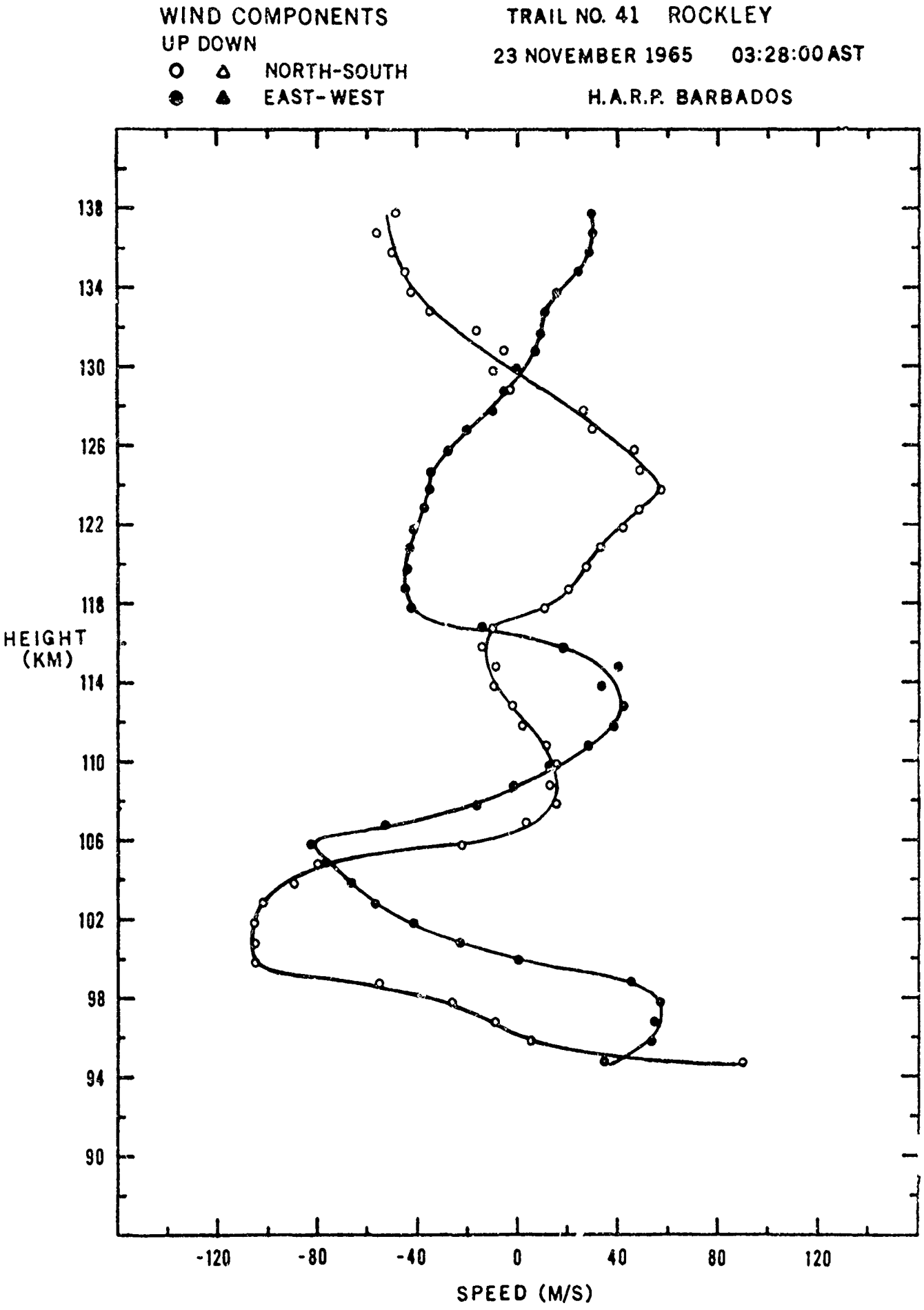



WIND DIRECTION
TRAIL NO. 40 QUEENS FORT
23 NOVEMBER 1965 01:31:00 AST
H.A.R.P. BARBADOS
UP TRAIL
DOWN TRAIL
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

TRAIL NO. 41 ROCKLEY

BARBADOS 23 NOVEMBER 1965 03-28-00 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
95.0	21.2	97.1	90.5	35.2	81.5	52.8
96.0	83.6	54.4	6.1	54.0	-4.9	54.1
97.0	98.3	55.4	-8.1	54.9	-19.0	52.1
98.0	114.4	63.2	-26.1	57.5	-37.2	51.0
99.0	140.3	71.9	-55.3	45.9	-63.4	33.8
100.0	179.8	105.1	-105.1	0.3	-103.0	-21.0
101.0	192.4	107.9	-105.4	-23.2	-98.5	-44.0
102.0	201.5	113.5	-105.6	-41.6	-95.0	-62.1
103.0	209.5	116.7	-101.6	-57.5	-87.9	-76.9
104.0	216.7	111.7	-89.5	-66.8	-74.1	-83.5
105.0	223.9	110.8	-79.8	-76.9	-62.6	-91.4
106.0	255.1	85.7	-22.1	-82.8	-4.9	-85.6
107.0	274.4	53.4	4.1	-53.3	14.8	-51.4
108.0	313.1	23.0	15.7	-16.8	18.8	-13.3
109.0	348.4	13.3	13.0	-2.7	13.3	0.0
110.0	40.0	19.9	15.2	12.8	12.3	15.6
111.0	67.8	30.4	11.9	28.0	6.0	29.8
112.0	87.5	38.6	1.7	38.6	-6.1	38.1
113.0	91.8	42.7	-1.3	42.6	-9.9	41.5
114.0	105.1	35.0	-9.1	33.8	-15.7	31.3
115.0	101.8	40.9	-8.4	40.1	-16.3	37.6
116.0	127.9	23.8	-14.6	18.8	-18.1	15.5
117.0	236.1	17.9	-10.0	-14.9	-6.8	-16.6
118.0	283.5	44.5	10.4	-43.2	18.9	-40.2
119.0	294.7	49.9	20.9	-45.3	29.6	-40.1
120.0	301.4	52.6	27.4	-44.9	35.9	-38.4
121.0	307.5	54.5	33.1	-43.3	41.2	-35.7
122.0	316.5	58.0	42.1	-40.0	49.3	-30.7
123.0	321.4	61.7	48.2	-38.5	55.0	-28.0
124.0	327.6	66.5	56.1	-35.6	62.1	-23.5
125.0	322.8	60.3	48.0	-36.5	54.4	-26.0
126.0	328.2	54.0	45.9	-28.5	50.7	-18.6
127.0	325.9	36.3	30.1	-20.4	33.6	-13.9
128.0	338.4	27.5	25.6	-10.1	27.1	-4.7
129.0	249.1	7.3	-2.6	-6.8	-1.2	-7.2
130.0	188.7	10.3	-10.2	-1.6	-9.7	-3.6
131.0	129.5	9.0	-5.7	6.9	-7.0	5.6
132.0	151.5	18.3	-16.1	8.7	-17.5	5.3
133.0	163.2	36.0	-34.5	10.4	-35.9	3.2
134.0	160.5	45.0	-42.4	15.0	-44.6	6.1
135.0	151.7	51.0	-44.9	24.2	-48.9	14.6
136.0	151.0	57.0	-49.9	27.6	-54.5	16.9
137.0	152.2	64.0	-56.6	29.9	-61.5	17.8
138.0	149.1	56.9	-48.9	29.2	-53.8	18.7


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO. 41 ROCKLEY
23 NOVEMBER 1965 03:28:00 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
106
102
98
94
90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

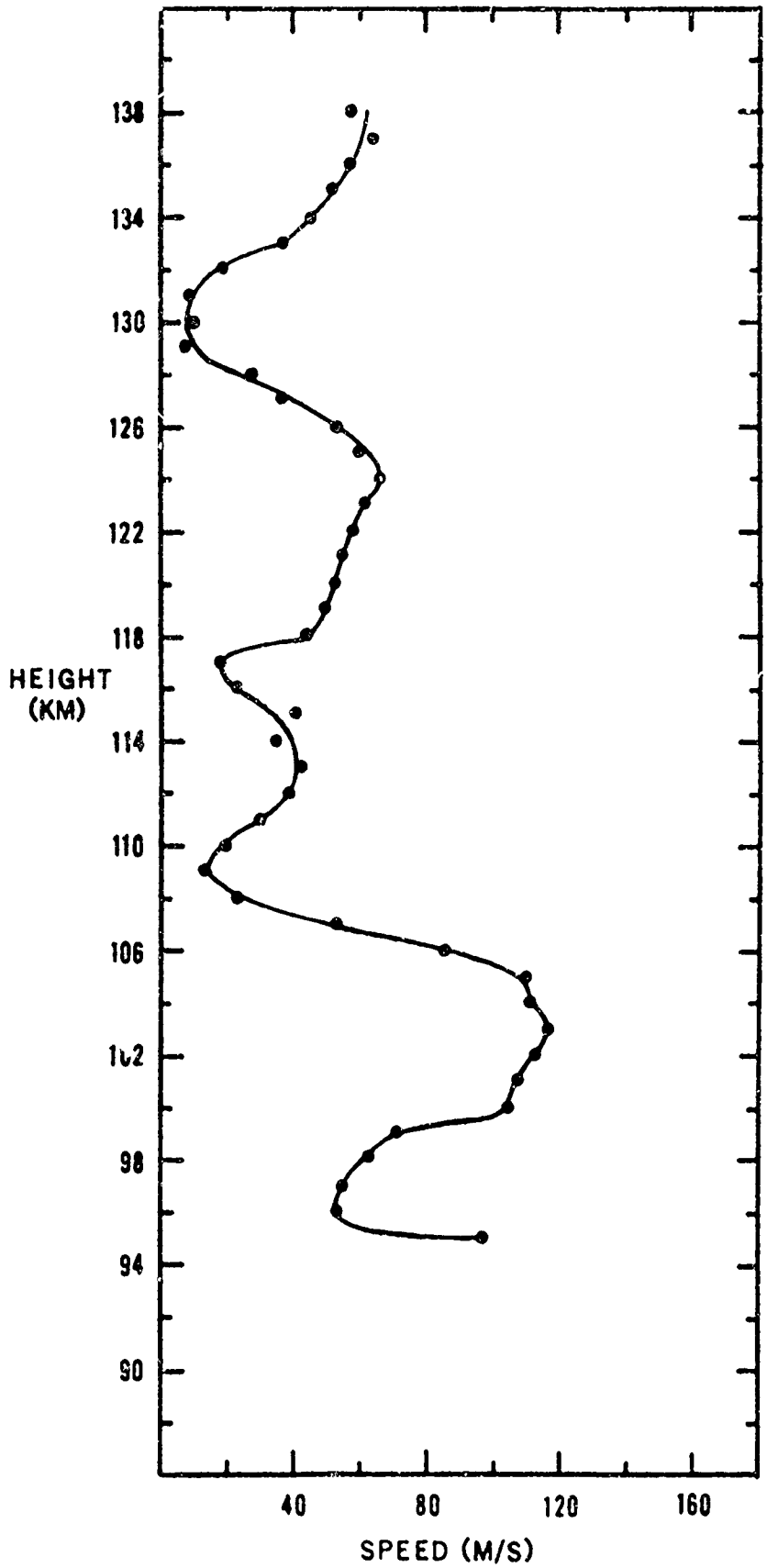
TRAIL NO. 41 ROCKLEY

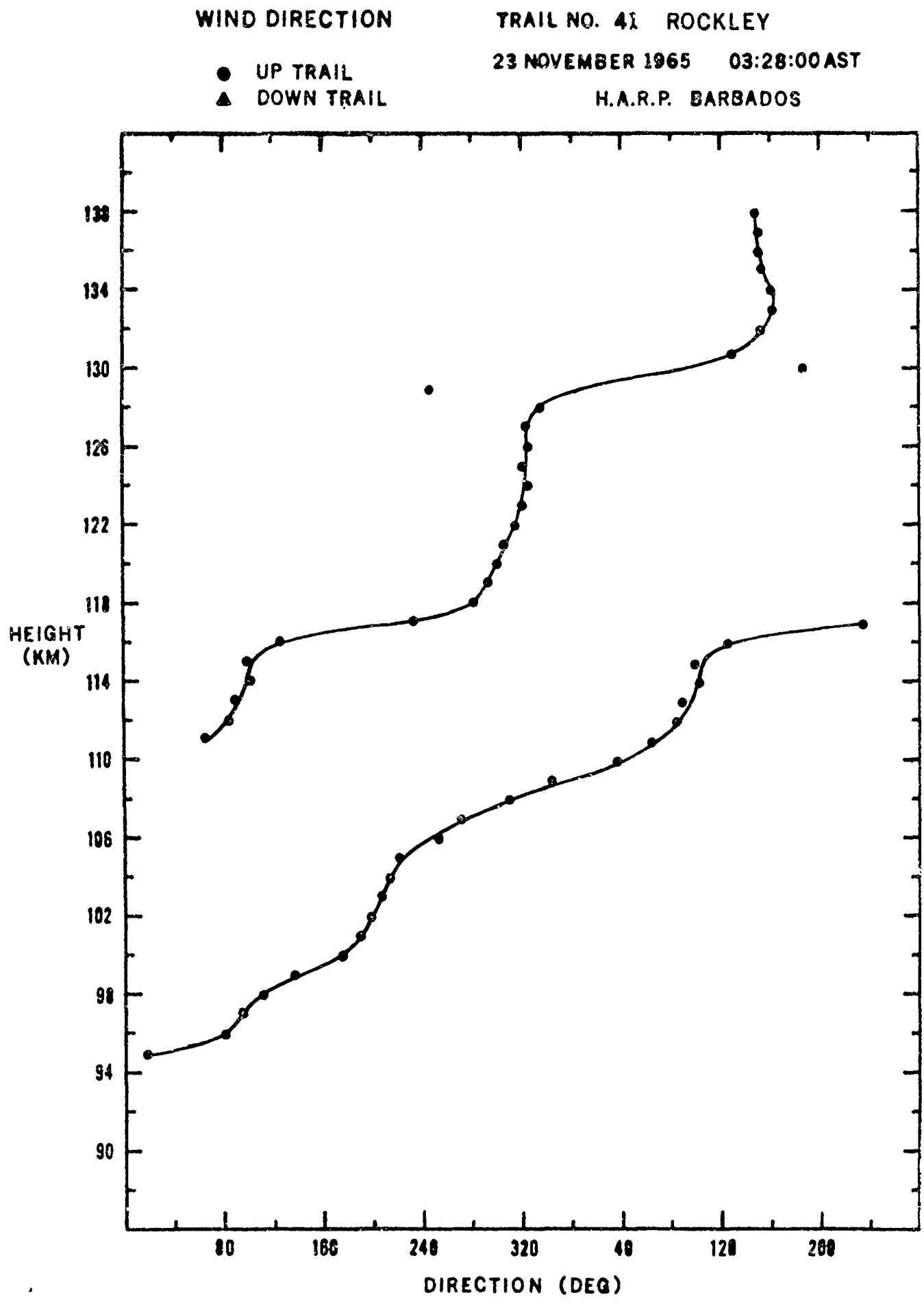
23 NOVEMBER 1965 03:28:00 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS




WIND DIRECTION
TRAIL NO. 41 ROCKLEY
23 NOVEMBER 1965 03:28:00 AST
UP TRAIL
DOWN TRAIL
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
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114
110
106
102
98
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90
80
160
240
320
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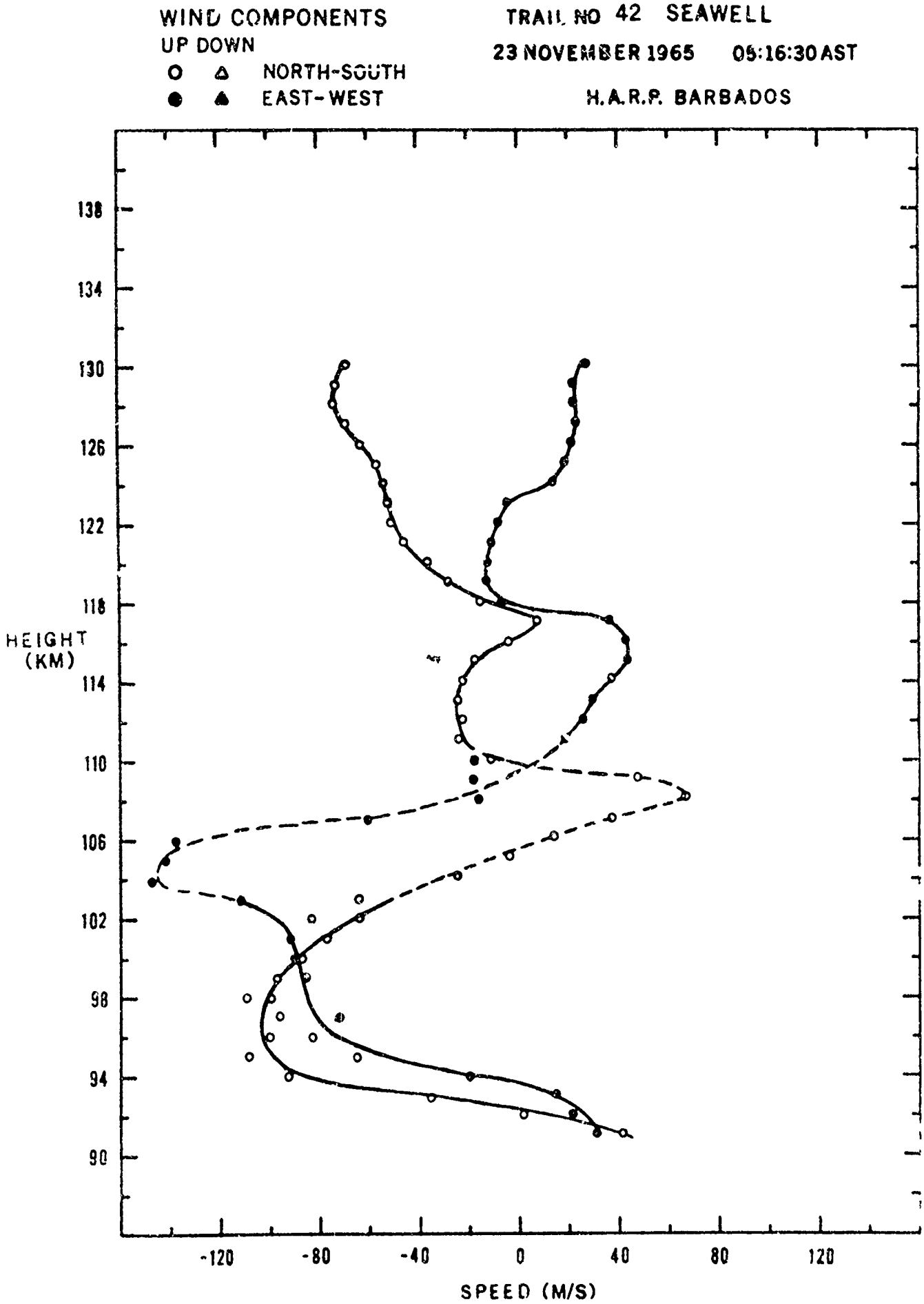
120
200
DIRECTION (DEG)

TRAIL NO. 42 SEAWELL

BARBADOS 23 NOVEMBER 1965 05-16-30 AST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
91.0	36.1	51.4	41.6	30.3	34.6	38.1
92.0	85.8	21.1	1.5	21.1	-2.8	21.0
93.0	157.1	37.8	-34.9	14.7	-37.2	7.3
94.0	192.1	94.8	-92.7	-19.9	-86.8	-38.2
95.0	211.1	126.4	-108.3	-65.2	-92.9	-85.8
96.0	219.5	130.6	-100.7	-83.1	-81.8	-101.7
97.0	216.9	120.6	-96.5	-72.4	-79.9	-90.4
98.0	222.3	147.5	-109.1	-99.2	-86.8	-119.2
99.0	221.3	129.4	-97.2	-85.4	-77.9	-103.3
100.0	225.9	125.6	-87.4	-90.2	-67.4	-106.0
101.0	230.0	119.7	-76.9	-91.7	-56.8	-105.4
102.0	232.3	105.0	-64.2	-83.1	-46.1	-94.4
103.0	239.8	128.5	-64.5	-111.1	-40.7	-121.8
104.0	260.7	148.8	-24.2	-146.8	6.0	-148.7
105.0	268.4	141.2	-3.9	-141.2	24.7	-139.1
106.0	276.0	137.8	14.5	-137.0	41.9	-131.2
107.0	302.1	71.2	37.9	-60.4	49.3	-51.5
[illegible]5.0	346.9	69.3	67.5	-15.7	69.3	-1.7
109.0	340.2	51.6	48.6	-17.5	51.1	-7.3
[illegible]0.0	237.8	19.4	-10.4	-16.4	-6.9	-18.2
111.0	140.0	30.6	-23.4	19.6	-26.9	14.5
[illegible]2.0	129.3	34.6	-21.9	26.8	-26.9	21.8
113.0	128.1	38.9	-23.9	30.6	-29.6	25.1
114.0	119.4	43.7	-21.5	38.1	-28.8	33.0
115.0	110.2	47.8	-16.5	44.8	-25.2	40.5
116.0	94.1	44.2	-3.2	44.1	-12.1	42.5
117.0	77.4	38.5	8.4	37.6	0.6	38.5
118.0	292.0	15.1	-14.0	-5.7	-12.6	-8.4
119.0	292.5	29.1	-26.9	-11.2	-24.1	-16.4
120.0	197.2	36.8	-35.2	-10.9	-32.3	-17.8
121.0	191.6	45.3	-44.3	-9.1	-41.5	-17.9
122.0	187.8	49.6	-49.2	-6.7	-46.8	-16.5
123.0	183.3	51.1	-51.0	-2.9	-49.4	-13.2
124.0	163.7	54.9	-52.7	15.4	-54.7	4.4
125.0	159.7	58.8	-55.1	20.4	-58.1	8.8
126.0	159.3	65.7	-61.4	23.3	-64.8	10.4
127.0	159.7	72.2	-67.7	25.1	-71.4	10.9
128.0	161.5	76.4	-72.5	24.2	-75.9	9.0
129.0	161.0	75.2	-71.1	24.5	-74.6	9.6
130.0	156.7	73.7	-67.7	29.1	-72.2	14.8


WIND COMPONENTS
UP DOWN
NORTH-SOUTH
EAST-WEST
TRAIL NO 42 SEAWELL
23 NOVEMBER 1965 05:16:30 AST
H.A.R.P. BARBADOS
HEIGHT (KM)
138
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114
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90
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

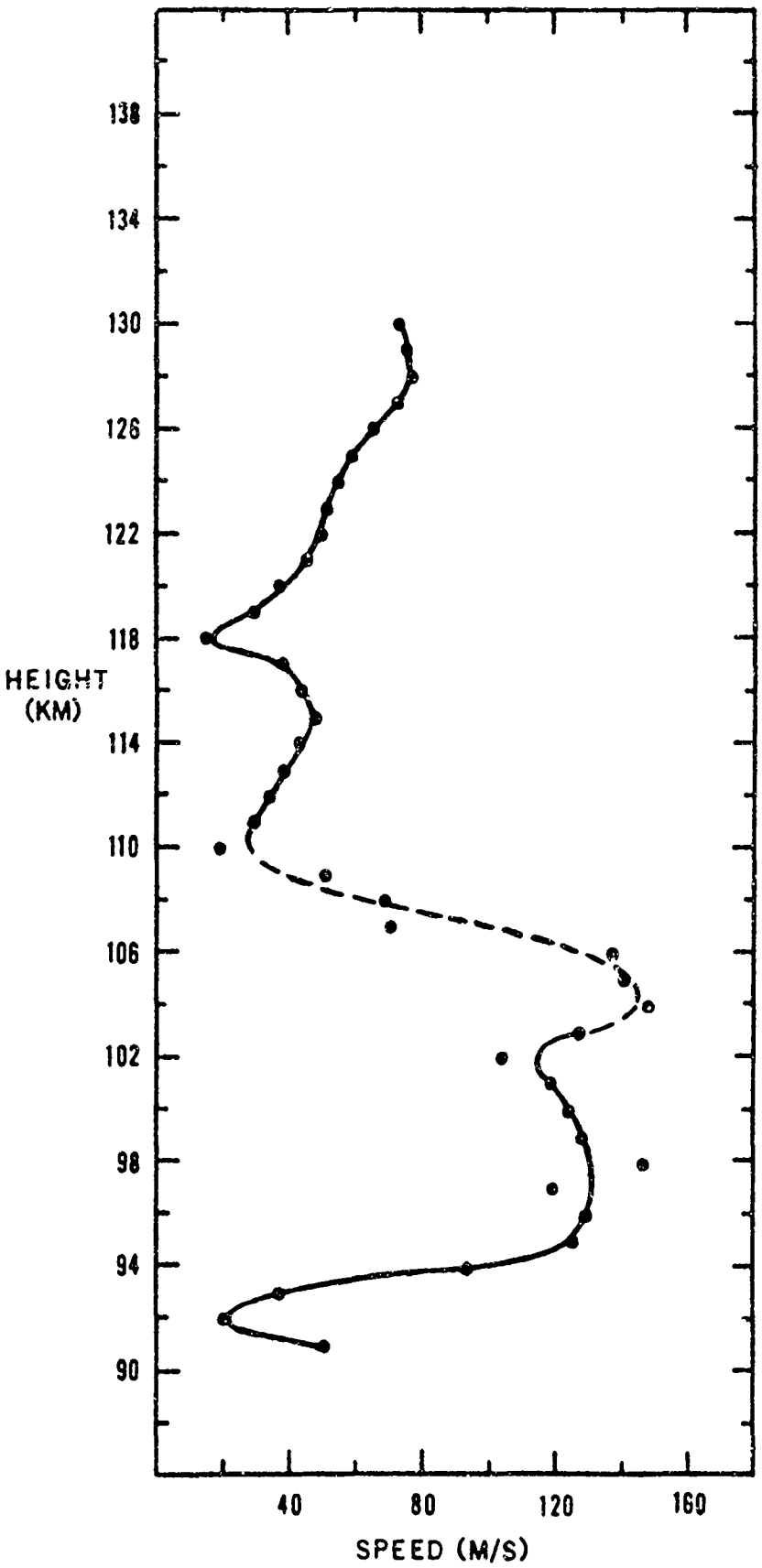
TRAIL NO. 42 SEAWELL

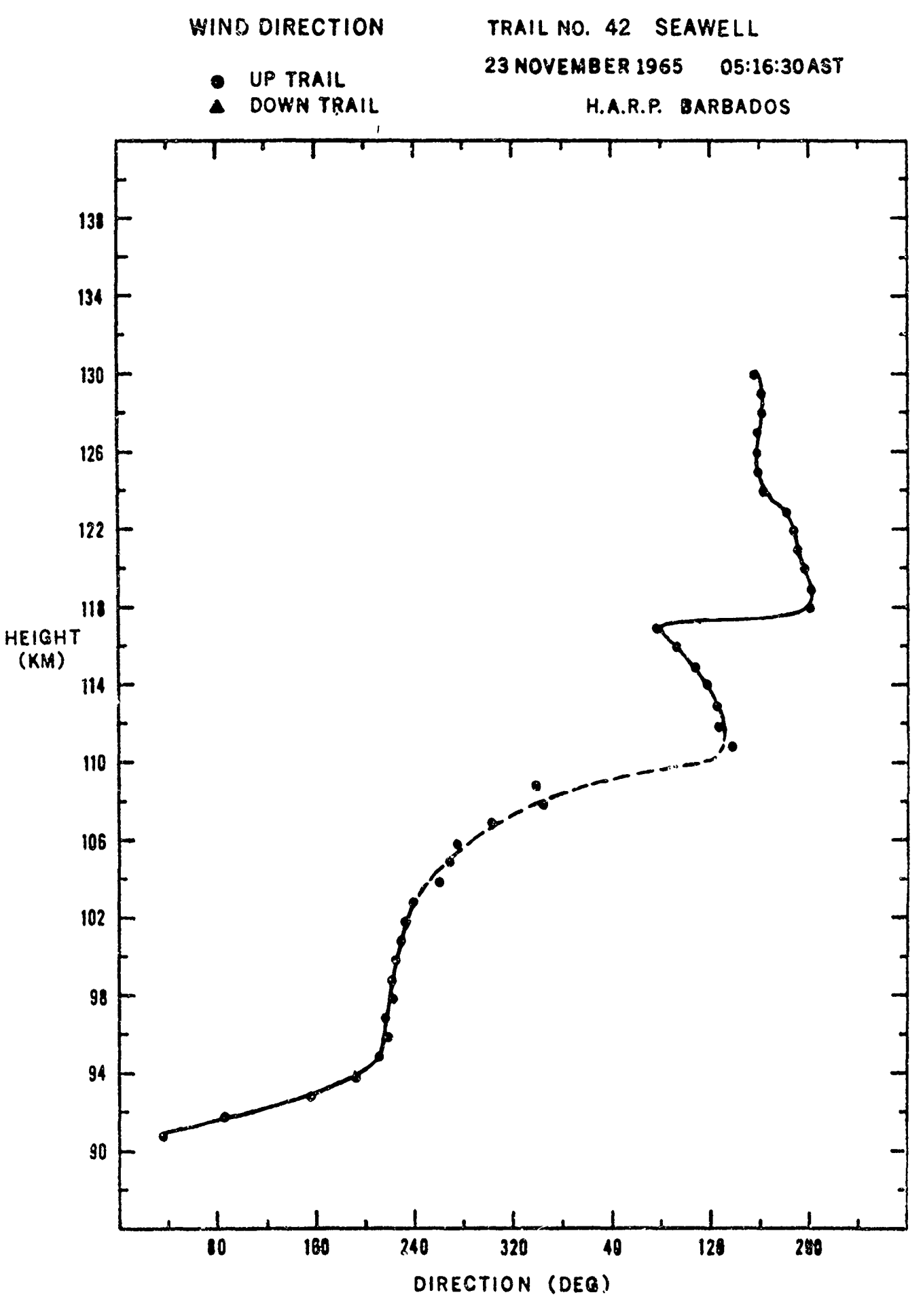
23 NOVEMBER 1965 05:16:30 AST

● UP TRAIL

▲ DOWN TRAIL

H.A.R.P. BARBADOS




WIND DIRECTION
TRAIL NO. 42 SEAWELL
23 NOVEMBER 1965 05:16:30 AST
UP TRAIL
DOWN TRAIL
H.A.R.P. BARBADOS
HEIGHT (KM)
138
134
130
126
122
118
114
110
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98
94
90
80
160
240
320
40
120
200
DIRECTION (DEG)

UNCLASSIFIED
Security Classification

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4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*
Robert L. Fuller

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13 ABSTRACT

On the night of 17-18 November 1965, six luminous trails were produced between 91km and 138km by the release of tri-methyl-aluminum from projectiles fired from a smoothbore sixteen-inch gun located on the West Indian island of Barbados (57.5°W, 13.1°N). An additional six trails were produced during the night of 22-23 November 1965. These trails were photographed from neighboring islands and analyzed to yield wind profiles. This report contains the tabulated wind data for all sixteen trails together with plots versus altitude of wind components, wind speed, and wind heading.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
HARP High Altitude Research Project Ionospheric Winds						

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Security Classification